INFN-LNF POSITIONS FOR "SUMMER STUDENT" GRANTS (2021)

Name of the project/experiment/group: LHCb
Title: Semileptonic b-hadron decays: tools for New Physics discovery
Description of the activity: One of the key assumptions of the Standard Model of fundamental particles is that the interactions of the various kind of charged leptons differ only because of their different masses.

Recent studies of semileptonic decays of B-mesons have resulted in observations that challenge lepton flavour universality (LFU) at the level of about three-four standard deviations. A confirmation of these results would point to new particles or interactions, and could have profound implications for our understanding of particle physics.

LHCb is one of the main experiments collecting data at the Large Hadron Collider accelerator. One of its primary goal is to study with high accuracy the properties of b-hadrons that are copiously produced in the proton-proton collisions at LHC. The LFU test results obtained at LHCb concern so far two classes of transitions in b-quark hadron decays. Measurements of highly suppressed flavour-changing neutral-current decays, $b \to s\ell^+\ell^-$, hint at a difference involving muons and electrons, while measurements of the more frequent tree-level charged current processes, $b \to c\ell^-\overline{\nu}_\ell$, hint at a difference between muons and taus. These two classes of decays present very different challenges, both experimentally and theoretically.

In the LHCb group in Frascati we are deeply involved in several studies involving b-hadrons, ranging from the study of LFU in semileptonic decays of the B_s mesons, like $B_s \to D_s^{(*)}\mu^-\overline{\nu}_\mu$ and $B_s \to D_s^{(*)}\tau^-\overline{\nu}_\tau$, and study of the rare $B_s \to \mu^+\mu^-$ decay.

The student will be involved on key aspects of the data analysis. Depending on his/her interests and when he/she will be with us, the work can focus on:

- the optimisation of signal selection and the study of a suitable sample to control the most dangerous backgrounds;
- the developments of novel algorithms to control efficiency determination;
- the improvements of the resolution of the signal kinematic;
- fit of the parameters of interest and limits on various New Physics models.

The student will learn how to handle big sample of data with modern tools typically used in High Energy Physics. In particular, in various stages of the work, there will be a large usage of modern Machine Learning techniques. Some knowledges in computing (e.g. python, C++, root,...) are desirable but not mandatory.

Additional information:
LHCb collaboration website for useful general information:
http://lhcb.web.cern.ch/lhcb/
Interesting papers on LFU tests with B-decays:
https://cerncourier.com/a/beauty-quarks-test-lepton-universality/
https://inspirehep.net/literature/1516196
https://inspirehep.net/literature/1842210

Period: June – July 2021 or September – October 2021
Tutor: Marcello Rotondo (marcello.rotondo@lnf.infn.it), Barbara Sciascia (barbara.sciascia@lnf.infn.it)
Tutor dates: June 1st - August 6th, September 1st – October 29th

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Name of the project/experiment/group: Mu2e
Title n. 1: Test of electronics and silicon photomultipliers of the Mu2e experiment
Description of the activity: The Mu2e experiment aims to improve the search for the Standard Model forbidden conversion of a muon into an electron. Discovery of such a signal is a clear indication of new physics. The detector is under construction at Fermi National Laboratory (US). The INFN-LNF group is leading the construction of the Electromagnetic Calorimeter to provide confirmation of the electron signal registered with a tracker system. The Mu2e calorimeter is a state of the art detector composed by 1350 un-doped CsI crystals, each one readout with two new generation UV-extended large area Silicon Photomultipliers (SiPMs) and two custom Front End Electronics (FEE) boards.
The large production of SiPMs and FEE is under completion. A semi-automatized station is under construction at LNF to calibrate the total gain (G_SiPM*G_FEE) of the system by illuminating the sensors with a pulsed LED. A scan as a function of the light yield will be performed by means of a rotating wheel. A scan of the response and resolution as a function of the applied bias to the sensors, as well as to the sensor temperature, is also foreseen. The student will follow up the tuning of the station and the measurement on the produced batches of glued SiPMs. A possibility to develop also the hardware DB connected to the set of measurements can be foreseen. *A summary paper will be written as a result of the work done with possibility of publication on a detector journal.*

Period: June – July 2021
Tutor: I. Sarra, S. Miscetti (ivano.sarra@lnf.infn.it), (stefano.miscetti@lnf.infn.it)
Tutor dates: June 1st – August 6th 2021
Required skills: Basic knowledge of C++, ROOT

Name of the project/experiment/group: Mu2e
Title N. 2: Development of DQM and DCS system for the calorimeter of the Mu2e experiment
Description of the activity: The Mu2e experiment aims to improve the search for the Standard Model forbidden conversion of a muon into an electron. Discovery of such a signal is a clear indication of new physics. The detector is under construction at Fermi National Laboratory (US). The INFN-LNF group is leading the construction of the Electromagnetic Calorimeter to provide confirmation of the electron signal registered with a tracker system. The Mu2e calorimeter is a state of the art detector composed by 1350 un-doped CsI crystals, each one readout with two new generation UV-extended large area Silicon Photomultipliers (SiPMs) and two custom Front End Electronics (FEE) boards.
A very sophisticated Trigger DAQ (TDAQ) system is under development. The TDAQ is based on software tools both on the data readout and on the trigger system. The LNF group is working on the definition and writing of the related SW modules needed for the Data Quality Monitor (DQM) and the Detector Control System (DCS ala slow control) for the calorimeter detector. The DQM is based on the construction of a set of histograms (1D, 2D, graphs, profiles) that have to be visualized automatically by the Run Control interface or by a standalone ROOT Application. The DCS is based on EPICS and allows to control the parameters both on TDAQ or on ethernet connected instrumentation. A possibility to develop or improve the firmware exists, as well as to collaborate with the TDAQ experts located at Fermilab by remote. *For a successful student, there will be the possibility to continue this job at Fermilab in the next future, if/when pandemics get reduced.*

Period: June – July 2021
Tutor dates: June 1st – August 6th 2021

Tutors: S.Giovannella (simona.giovannella@lnf.infn.it),
S.Miscetti (stefano.miscetti@lnf.infn.it)
Required skills: Good knowledge of C++ and programming languages, ROOT. Preference for students with an informatic profile

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Name of the project/experiment/group: Mu2e
Title N. 3: Data analysis of Cosmic Ray data of the Mu2e calorimeter large size prototype (Module-0)
Description of the activity: The Mu2e experiment aims to improve the search for the Standard Model forbidden conversion of a muon into an electron. Discovery of such a signal is a clear indication of new physics. The detector is under construction at Fermi National Laboratory (US). The INFN-LNF group is leading the construction of the Electromagnetic Calorimeter to provide confirmation of the electron signal registered with a tracker system. The Mu2e calorimeter is a state of the art detector composed by 1350 un-doped CsI crystals, each one readout with two new generation UV-extended large area Silicon Photomultipliers (SiPMs) and two custom Front End Electronics (FEE) boards.
A large size prototype (dubbed Module-0) has been assembled at LNF with 51 CsI crystals. A good fraction of the detector has been equipped with the final SiPMs and final FEE electronics. A Vertical Slice Test of the system will be carried out by reading out the channels with the final Mezzanine Board, that allows a control of the settings and a continuous logging of the detector parameters (HV, T and I), and the final Digitizer Board (DIRAC), that allows digital recording of the detector signals. We foresee to acquire three sets of data: (i) noise runs with a random trigger, (ii) Cosmic Rays data triggering on a set of external scintillation counters and (iii) laser runs by illuminating with a pulsed-laser each sensor by means of a bundle of optical fibers.
The student will be in charge of reconstruct and analyze the large quantity of data collected to determine: the calibration points for energy and timing, the timing resolution and the stability of detector parameters, detector response and calibration along the running time. *A summary paper will be written as a result of the work done with possibility of publication on a detector journal.*

Period: June – July 2021
Tutor dates: June 1st 2021 – August 6th 2021;
Tutors: E. Diociaiuti (eleonora.diociaiuti@lnf.infn.it),
S.Giovannella (simona.giovannella@lnf.infn.it)
Required skills: good knowledge of C++, good knowledge of ROOT

Name of the project/experiment/group: CYGNO
Title: Advanced detectors for directional Dark Matter search
Description of the activity: At the National Laboratory of Frascati is under design the CYGNO project. CYGNO is a new proposal supported by INFN, the Italian National Institute for Nuclear Physics, within CYGNUs proto-collaboration (CYGNUS-TPC) that aims to realize a distributed observatory in underground laboratories for directional Dark Matter (DM) search and the identification of the coherent neutrino scattering (CNS) from the Sun. CYGNO is one of the first prototypes in the road map to 100-1000 m^3 of CYGNUs and will be located at the National Laboratory of Gran Sasso (LNGS), in Italy, aiming to make significant advances in the technology of single phase gas-only time projection chambers (TPC) for the application to the detection of rare scattering events at keV energy threshold.

During he fellow, the candidate will take part to the design and characterization of the Optical Read Out technique based on Micro Pattern Gas Detector (MPGD) amplification of the ionization and on the visible light collection with a sub-millimeter position resolution sCMOS (scientific COMS) camera. This type of readout - in conjunction with a fast light detection - allow on one hand to reconstruct 3D direction of the tracks, offering accurate sensitivity to the source directionality and, on the other hand, a high particle identification capability very useful to distinguish nuclear recoils.

Period: June – July 2021 or September – October 2021
Tutor: Giovanni Mazzitelli (Giovanni.mazzitelli@lnf.infn.it)

Name of the project/experiment/group: PADME
Title: Search for dark matter signals at LNF with PADME
Description of the activity: There are models attempting to solve the dark matter problem, as well as the muon (g-2) anomaly, postulating the existence of a low-mass spin-1 particle (A') that would possess a gauge coupling of electroweak strength to dark matter, and a much smaller coupling to the Standard Model (SM) hypercharge. The PADME experiment, by using the positrons of the Frascati National Laboratory (LNF) LINAC, is searching for invisible decays of the dark photon by measuring the missing mass of the process e^+e^- -> gamma A', with the A' undetected. The measurement requires the determination of the 4-momentum of the recoil gamma and the rejection of all possible source of background. PADME is an international collaboration that comprises Bulgarian, Hungarian, Italian and American researchers. The detector has been installed on the LNF positron beam-line in 2018 and has been commissioned with beam in 2019. From September to December 2020, the first data taking took place and 5 $\times 10^{12}$ positron-on-target have been collected. Now, an intense activity of data analysis is ongoing. The candidate should have a bit of knowledge of C++ and of ROOT data analysis framework.

Period: 1 June – 9 August 2021; or 1 September – 30 October 2021
Tutor: Paola Gianotti (gianotti@lnf.infn.it)

Name of the project/experiment/group: Ecloud-mitigation/ARYA/GroupV-LdS
Research Field: R&D in Vacuum Science and Technologies
Title: Study of material properties of impact to e-cloud related instabilities for the EIC
Description of the activity: The mitigation of collective effects (e-cloud, etc.) and impedance driven instabilities in circular accelerators have been identified as important issues for the newly funded Electron Ion Collider (EIC) to be built in USA in the next years. The Material and Surface Science laboratory (MASS-Lab) in Frascati can significantly contribute to all those items. In particular we can fully characterize a material in terms of its surface composition, its Secondary Electron Yield, its stability versus time, electrons (eventually ions) bombardment, their vacuum stability versus thermal fluctuations, the chemical modifications occurring during irradiation and/or gas adsorption, etc. and all this in a temperature range spanning from 10 to 300 K.
The successful candidate will get acquainted with the different issues to be studied and with the various techniques used to obtain the desired information.

Period: June – July 2021 and/or September – October 2021
Tutor: R. Cimino (Roberto.cimino@lnf.infn.it),
M. Angelucci (marco.angelucci@lnf.infn.it)

Name of the project/experiment/group: VIRGO/aLIGO Gr2- LdS
Research Field: R&D in Vacuum, Material Science and Technologies for Gravitational waves detectors
Title: Neutralization of the electrostatic charge on test mass mirrors in gravitational wave detectors
Description of the activity: The search to mitigate all potential effects that can detrimentally influence the sensitivity of present and future gravitational wave detectors have triggered specific R&D worldwide. One of the many issues to be solved not to affect the desired sensitivity is the noise induced by the electrostatic charge forming on test mass mirrors. Here we want to investigate a novel method to neutralize test masses electrostatic charge that could be performed in UHV and could easily be applied to cryogenic mirrors by using an electron flux of variable (low) energy electrons. The successful candidate will get acquainted with the different issues to be studied and with the various techniques used to obtain the desired information.

Period: June – July 2021 and/or September – October 2021
Tutor: R. Cimino (Roberto.cimino@lnf.infn.it), L. Spallino (luisa.spallino@lnf.infn.it)

Name of the project/experiment/group: SHERPA
Title: Slow High-efficiency Extraction from Ring Positron Accelerator
Description of the activity: Experimental activity at the LNF Beam Test facility to characterize bended crystals to realize non-conventional extracted positron beams from the DAFNE complex.

Period: June – July or September – October 2021
Tutor: Marco Garattini (marco.garattini@lnf.infn.it)

INFORMATIONS

- Accommodation: students may be accommodated, free of charge, in the LNF guesthouse (for information: http://www.lnf.infn.it/funz/concorsi/foresterie.html).
- Lunches at the LNF canteen (Monday-Friday) are free of charge.
- LNF Summer closing period: 9-22 August.

Local Exchange Program Contacts:
Catalina Curceanu (coordinator)
M. Cristina D'Amato (secretary)
Phone +39-06-94038133