Gran Sasso Summer Institute 2014 - Hands-On Experimental Underground Physics at LNGS

Monday, 22 September 2014 - Friday, 3 October 2014

LNGS

Scientific Programme

<font size="3">The aim of Gran Sasso Summer Institute is to provide graduate students and young post-docs with the opportunity of actively working for two weeks with the researchers of the Gran Sasso National Laboratory (**LNGS**), the worldwide largest underground experimental facility at present.

The main research field at the Gran Sasso National Laboratory is the so-called astroparticle physics, lying at the intersection of particle physics, astrophysics and cosmology. Main items of research are: neutrino physics, cross-section measurements of rare nuclear processes of astrophysical relevance, neutrino-less double beta decay, dark matter searches, low rate counting for radioactivity measurements.

In the underground laboratories of LNGS several projects are looking for rare processes with implications in particle physics, astrophysics and cosmology. Neutrino detectors (**BOREXINO, ICARUS, LVD, OPERA**) are aimed at identifying and characterizing neutrinos from different natural sources, like the Sun, the Earth, the atmosphere, supernovae, or artificially produced by accelerators and other sources. Large detectors look for neutrino-less double beta decay in different isotopes (**CUORE, GERDA**). Dark matter and WIMP searches are performed in detectors exploiting complementary techniques (**CRESST, DAMA, DarkSide, Xenon**). Nuclear cross sections relevant in astrophysical and cosmological processes are directly measured in an underground facility (**LUNA**). Small effects due to general relativity (**GINGER**) are studied as well. New experimental technologies are continuously developed to be implemented in underground set-ups (**COBRA, LUCIFER**).

The experimental topics, techniques and methods involved in the research activities at LNGS, will be addressed by international lectures.
By the end of the two weeks, students will be asked to report the results of their experimental activity performed at the Laboratory. The reports will be published as proceedings papers in a peer-reviewed journal.

LECTURES

PROPOSED PRACTICAL ACTIVITIES

Please note that the program of practical work may change. When applying, you can give preference for 2 topics. Typically 2 participants are working on one topic.

1) ^{210}Po is an important source of background in most of rare processes experiment. We plan to have a student learning about this aspect and using tools to measure the ^{210}Po rate in the **BOREXINO** experiment.

2) Pulse Shape Discrimination is an important tool to disentangle signal and background. We plan to have a student learning about a figure-of-merit based on the pulse shape discrimination in the direct dark matter search experiment, **DarkSide-50**.

3) The students will be involved in the activity of energy calibration of **GERDA** detectors. GERDA

searches for neutrinoless double beta decay with germanium detectors. The germanium semiconductors are calibrated with ^{228}Th sources, which are lowered in the GERDA cryostat. The collected energy spectrum is used to derive the calibration curves, which relate the experimental value of the energy to the nominal one. The energy resolution of GERDA detectors will be also determined.

4) Nuclear emulsion detectors. Scanning with automatic microscopes and particle tracking: signal to background discrimination using a likelihood analysis. Application to neutrino physics (**OPERA** experiment), muon radiography of volcanos and Dark Matter searches.

5) The students will carry out the experimental activity in the frame of the **LUCIFER** project. The activity foresees the assembly and operation of bolometric detectors. In the specific, the students will directly put hands on the detector, designing and constructing a scintillating bolometer. The detector will be installed in a dilution refrigerator and operated at ~10 mK. Finally, the students will analyze some preliminary data from the running set-up.

6) In framework of the **CRESST** Dark Matter Search students can follow a test measurement of a typical CRESST detector carried out in the CRESST test facility. The small research project includes the assembling, mounting and operation of a cryogenic detector consisting of a scintillating crystal working as target for particle detection and a light detector. The detectors are operated as bolometers in a dilution refrigerator at around 10 mK. Students will be involved in the mounting of the detector as well as in the cool down process of the cryostat. Furthermore students will get an inside in the operation of such cryogenic detectors as well as in the analysis of data taken with these detectors.

7) CNGS neutrino beam oscillation studies with the **ICARUS T600** LAr-TPC. ICARUS is the largest Liquid Argon Time Projection Chamber (LAr-TPC) so far ever built and operated (760 tons of ultra-pure LAr). This detection technology, after decades of R&D studies, thanks to its excellent performances in term of spatial resolution, calorimetry and particle identification, is now ready to give its scientific contribution in the study of the neutrino oscillation phenomena. The practical activity of this topic will be related to the analysis of the CNGS beam neutrino events in the ICARUS T600 detector. Students will have the opportunity of facing with the full neutrino events reconstruction with the ICARUS software of analysis. Tasks related to the study of the neutrino-Argon cross section systematics in the frame of the CNGS muon neutrino disappearance will be also proposed.

8) Scintillating crystals and plastics emit light when interacting with charged particles. In conjunction with photodiodes or photomultipliers these materials can be used as particle detectors. Their performance is a function of the type and energy of the detected particle, the temperature and thickness of the active material and the type of photosensor. The proposed activity is in the framework of Nuclear Astrophysics (**LUNA**) and Dark Matter fields (**Dark Side**); the students will investigate various combinations of materials using an experimental setup in the surface laboratory.

9) Background and signal modeling of liquid xenon detectors for Dark Matter direct detection. Studying and modeling the background and the signal of an experiment is one of the main analysis tasks that any experimental activity involves. The students will study the background and signal calibrations of the **XENON100** Dark Matter (DM) direct detection experiment and will be guided through the different steps that allow the modeling of the detector response and to insert it into a frequentist analysis framework.

10) A LXe test facility for the characterization of the R11410 PMTs to be used in the **XENON1T** Dark Matter direct detection experiment. The Hamamatsu R11410 photo-multiplier tubes (PMTs) are the core of the **XENON1T** detector: 2 arrays of 250 such PMTs in total will be detecting the scintillation light produced in the liquid xenon sensitive volume. All those PMTs have to be tested in liquid xenon (LXe) prior to be employed in XENON1T. A cryogenic facility has been built by the local italian XENON groups and will be used to characterize the performances of the R11410 PMTs in LXe. The student will take part of this activity and will be involved in both the cryogenic and operation of the detector and in the analysis of the data that will be taken.

11) Improving the sensitivity of **CUORE** is the target of many ongoing R&Ds. In particular rejecting alpha induced background is one of the crucial goals. The students will be involved in the characterization of scintillation films at low temperature designed to tag ^{210}Po alphas. The results will be used to extract the sensitivity of a CUORE upgrade with rejection capabilities. The work will be carried on in a dedicated facility (the **ABSURD** cryocooler).

12) The **CUORE** cryostat, capable to cool down a 1 Tonne detector to a T of ~ 10 mK is the crucial equipment necessary to run the experiment. The cryostat is currently under commissioning. Students will be introduced to cryogenic technologies and will have the chance to participate to the commissioning operation. The predicted cryostat behavior will be compared with data using a semi-empirical thermodynamical model.

13) **GINGER** is a project aiming at measuring the gravitomagnetism of the earth by using an array of ringlasers. RingLasers are the most sensitive and accurate sensors of angular rotation, at the moment the most sensitive device has a sensitivity of fractions of pico-radiants. A 3.6 side square ring laser is now under construction inside LNGS and will hopefully be operational during the summer institute. The program of the GINGER team for the Summer-Institute is divided in two parts: “Ginger and the General Relativity” and “the ring lasers and its data analysis”. In the first week the support will be provided by experts in general relativity and laser. In the second week the student will experience the experimental work of the ring laser and its data analysis. The experimental work will depend on the status of our installation. Our apparatus is aiming and fundamental science, but it can access to signals relevant for geodesy and geophysics.

14) Gamma-ray spectroscopy with High Purity Germanium detectors in the framework of Nuclear Astrophysics (**LUNA** experiment) and ultra low background measurements (ultra low background facility **STELLA** (SubTErranean Low Level Assay)). The activity will comprise energy calibration, determination of efficiency, and measurements of radioisotopes (half-life determination, gamma-gamma cascades).

15) In this project a scientific computing environment, including **GEANT4** and **ROOT**, will be set up on a virtual machine of the Unified **LNGS IT** Environment (**U-Lite**). The system will be used for simulation and analysis of data obtained with a gamma ray detector at the **LUNA-400** accelerator in the underground laboratory of LNGS.

16) Determination of elements in trace by using Mass Spectrometry Technique:

- Introduction to Mass Spectrometry

(principle of working, field of use, type of Mass Spectrometry)

- Sample preparation

(understanding issues about potential contamination of the sample)

- Mass Spectrometry tune up

(set up of parameters, how to improve instrument sensitivity)

The target of this activity is to give to the student basic information about this refined technique mainly used at LNGS to determine radio purity of materials used by the experiments to build their particle detectors. During this stage the student will take part to the analysis carried out at the chemistry laboratory.

17) Design project and characterization of preamplifiers for SiPM devices. Design project and characterization of cryogenic low background preamplifiers for Photo-Multiplier Tubes.