PIRE-GEMADARC 2020 Summer Research Program: Candidate Research Projects for Undergraduate Students at the Institute of Physics, Academia Sinica, Taiwan.

The Particle Physics Group at the Institute of Physics, Academia Sinica (AS), expects to host students to conduct research on campus in summer of 2020 through the PIRE-GEMADARC program. Candidate research projects and their respective supervisors are listed as follows.

We expect students would be based at the AS campus during the period of May 20 to July 13, supported by the GEMADARC. Extended stay till end of August supported by AS is possible, upon mutual agreement with supervisors.

Further inquiries can be made to the coordinator Dr. Henry Wong at email: htwong@phys.sinica.edu.tw .

1. **Background Studies of Future Germanium Double Beta Experiments**
   Faculty Supervisor: Dr. Henry T. Wong

   Search of neutrinoless double beta decay is an area of active research with intense world attention. We will study the projected sensitivities in next-generation ton-scale projects, and how they are related with achieved background and how further improvement can be realized. We will use the tools on low radioactivity techniques as well as GEANT4 simulation software package.

2. **Research and Development of Next Generator Calibration System for Gravitational Wave Observatories**
   Faculty Supervisor: Dr. Henry T. Wong

   The coming generation of calibration system for gravitational observatories is expected to rely on – rightfully – gravitational effects, rather than the currently adopted electromagnetic interactions. We will work on various hardware as well as data acquisition and analysis projects on prototypes of such calibration systems, with goals of characterizing and devising improvement their performance.

3. **Improving the determination of proton and pion quark density distributions**
   Faculty Supervisor: Dr. Wen-Chen Chang

   Drell-Yan process involves the quark-antiquark interactions during the collisions of two hadrons. With the recent availability of the proton-induced Drell-Yan data from the SeaQuest/Fermilab experiment, and the pion-induced Drell-Yan one from the COMPASS/CERN experiment, the impact of these new data sets to the existing quark density distributions of protons and pions will be investigated. This study will be carried out within the global analysis framework of xfitter software package.

4. **Design of muon-identification detector**
   Faculty Supervisor: Dr. Wen-Chen Chang

   To carry out the measurement of exclusive Drell-Yan processes in E50 experiment at J-PARC, Japan, we are going to build up a muon-identification (muID) detector. This detector is composed of tracking device for charged particles, and stopping materials for hadrons. The design is to be optimized in term of stopping power of hadrons, good rejection of decay-in-fly mesons, as well as the proper penetration of muon tracks. We will study the design of muID detector using the GEANT4 simulation package.

5. **Supernova neutrinos**
   Faculty Supervisor: Dr. Meng-Ru Wu

   The detection of roughly 20 electron antineutrinos from the core-collapse supernova explosion happened in Large Magellanic Cloud in 1987 (SN1987a) not only successfully provided qualitative confirmation of the supernova theory, but also offered various implications on neutrinos and physics beyond the Standard Model (bSM). With the expected supernova occurence rate of ~ 0.5 - 2 per century in our Milky Way, the detection of thousands of neutrinos from the next Galactic, with detectors capable of seeing all flavors, may be on the horizon. To get ready for this once-in-a-lifetime event and get maximal scientific returns, further improved theoretical understanding of supernova neutrinos and their implications need to be done. Interested students can select to work on related projects including: i) modeling supernova neutrino signals, ii) utilizing the future supernova neutrino signals to learn about the yet-unknown properties of neutrinos, iii) constraining/revealing candidates of bSM physics with supernova neutrino detection.

6. **Dark Matter and Dark Cosmic Ray**
   Faculty Supervisor: Dr. Yue-Lin Sming Tsai

   Ref. [arXiv:1810.10543] proposed a new method of dark matter (DM) search to detect the scattering between DM and cosmic rays (CRs) proton. By using similar idea of both elastic and inelastic scattering of galactic CRs with DM, one can probe DM-proton and DM-electron interactions with DM mass at the MeV scale. The basic idea behind this scheme is that CR proton and electron scatter with DM particles during their propagation and lose energy in those collisions which may also alter the observed CR spectra. Apart from searching this signal from cosmic ray, we may also cross-compare with other possible detections, e.g. the neutrino, gamma-ray, and radio telescopes, in order to understand the nature and properties of DM. The numerical tool will be used is GALPROP v50.

7. **Radiation detectors for medical applications**
   Faculty Supervisor: Drs. Ming-lee Chu, Dr. Chih-hsun Lin

   In high-energy experiments, several types of detectors are used to detect particle trajectories, energies and speeds. Those detectors also have many medical applications, including imaging in medical diagnosis and assurances in radiation therapy. In this summer research session, we will show you the principle of different types of detectors and their medical applications. We will also provide hand-on training to operate at least one type of detector to measure physics quantities.

8. **Application of GPU and Machine Learning for proton therapy and biomedical imaging analysis with Big Data**
   Faculty Supervisor: Drs. Eric Yen, Chih-hsun Lin, Shih-Chang Lee

   Adopting technologies for nano-second time scale and micrometer spatial scale gamma-ray imaging over a large detection area developed in experimental particle physics to collect big data in real time during proton therapy and integrating with artificial intelligence analysis of on online and offline data with fast GPU computing, the therapy can be personalized to improve the efficiency and quality of treatments significantly. The study aims to accelerate the simulation by GPU computing based on Geant4. We also hope to build up a prototype to be able to learn from more test datasets progressively in considering the beam parameters as well as personal characteristics.