Department of Physics

D – High Energy Physics Honours Projects 2014

(Supervisors: Prof Anthony Thomas, Prof Tony Williams, Dr Ross Young, Dr Paul Jackson & Dr Martin White)

D-1 Experimental High Energy Physics (**Jackson, White**)

D-2 Theoretical High Energy Physics (**Thomas, White, Williams & Young**)

D-3 High Energy Physics Phenomenology (**Jackson, Thomas, White, Williams & Young**)

The research activities of the High Energy Physics (HEP) group in the Department of Physics are largely carried out under the umbrella of the ARC Centre of Excellence for Particle Physics at the Terascale (CoEPP) of which Adelaide is one of four nodes (University of Adelaide, University of Melbourne, Monash University and the University of Sydney).

D-1

EXPERIMENTAL HIGH ENERGY PHYSICS

(Supervisors: Jackson, White)

Our group works on the ATLAS experiment at the CERN Large Hadron Collider. As a member of this international collaboration we have a variety of responsibilities and activities, all of which can be joined at the honours level. We are performing several analyses of ATLAS data searching for physics beyond the Standard Model using new techniques invented in Adelaide. With the discovery of the Higgs Boson in 2012 (and the award of the Nobel prize in 2013) applying this constraint to searches at the LHC is extremely topical. Searches being pioneered in Adelaide include those for direct production of third generation supersymmetric particles, searches involving heavy leptons (e.g. taus) and other pair produced new states. These are complemented by an inclusive search for displaced vertices arising from long-lived heavy particle decays. Core techniques in Monte Carlo generation, simulation and charged particle tracking can also be studied to impact a broad range of measurements.

Our group is designing and testing new methods for readout of the data from the ATLAS experiment through fast data acquisition electronics. There are opportunities to develop software for the current detector system and for the upgraded high luminosity LHC running. We are further involved in Beam Loss Monitors for studies that will be used in the design of the protection system for Compact Linear Collider design, the next big machine in high energy physics. ATLAS data analyses are intimately related to projects in phenomenology (see Section D-3) and machine learning techniques to study constraints on signatures of dark matter. These studies combine a variety of collider physics and astrophysical sources.

D-2

THEORETICAL HIGH ENERGY PHYSICS

(Supervisors: Thomas, White, Williams, Young)

It is an exciting time to be a physicist with the apparent recent discovery of the Higgs Boson as predicted by the Standard Model and with being on the verge of discovering a rich landscape of new physics Beyond the Standard Model (BSM); despite its success at explaining an enormously wide range of known physical phenomena, the current Standard Model describes only the behaviour of ordinary matter, which is a mere 4.6% of the universe's total mass-energy content! Dark matter accounts for around 23% and dark energy accounts for the remaining 72% of the universe's mass-energy.

Evidence from gravitational lensing, galactic rotation curves and the cosmic microwave background radiation strongly suggests that approximately 23% of the universe's mass-energy and 83% of the mass is comprised of the mysterious quantity known as dark matter. There are many searches underway to probe the nature of this dark matter, both directly and indirectly, including cryogenic detectors buried deep beneath the ground.

In addition to the mysteries of dark matter and dark energy, there are extremely compelling reasons to believe the Standard Model is not the complete story and that it must inevitably be extended to include BSM. The apparent unification of the electromagnetic, weak and strong forces at the scale of 10^{16} GeV strongly argues for the existence of so-called Grand Unified Theories (GUTs), which include all three in a single unified model. In addition, the quantum effects of gravity can no longer be ignored at scales of 10^{19} GeV (the Planck scale) and at such a scale we need to build a Theory of Everything that includes gravity.

The available projects include supersymmetry (SUSY), GUTs, dark matter, extra-dimensional models, composite Higgs models, and scale invariant theories. Projects will typically involve one or more of these concepts. The projects will involve building and studying predictions of models of BSM physics and will be most suited to students with either a theoretical interest or a combined theoretical plus computational interest.

D-3

HIGH ENERGY PHYSICS PHENOMENOLOGY

(Supervisors: Jackson, Thomas, White, Williams, Young)

Phenomenology is the interface between theoretical and experimental high energy physics. While there is some overlap with D-2 above, the emphasis on these projects is in performing extensive and careful calculations of particle physics models so as to allow a direct comparison with experimentally measurable quantities. As explained above, the Standard Model (SM) cannot be the final answer and any theory of new physics should show up in lots of experiments including high-energy accelerator searches (such as the Large Hadron Collider and previous collider experiments), neutrino mass and mixing data, direct and indirect dark matter search experiments, low energy precision measurements, flavour physics, rare decays and in cosmology. The challenge of the phenomenologist is to calculate in detail the expected signals in each of these experiments, and to work out which new theories of physics are still viable given current measurements and which can be tested in new accelerators should they be constructed.

The Adelaide High Energy Physics group is heavily involved in the detailed phenomenology of supersymmetry (SUSY), including calculations in non-standard SUSY models, SUSY dark matter studies and the invention of new techniques for finding supersymmetric particles at the Large Hadron Collider. We also study the detailed observable phenomenological consequences of non-SUSY scenarios, including extra dimensional scenarios, effective dark matter models and general grand unified theories.

Finally, the Adelaide group is leading an international effort to take all current astrophysical and particle data to measure generic new theories of physics using state of the art computational techniques. We welcome applications from students wishing to do a combination of experimental, computational and theoretical work.