Robert Craig Group

Research Statement

What are the most fundamental pieces of our Universe? What are their properties and how do they interact with each other to form the structure and the phenomena we observe? These are the questions that keep me up at night and excited about my career.

Answering these questions is the goal of high energy experimental particle physics. In this field, large accelerators are used to force particles to collide at extremely high energies. Higher energy particles have a smaller wavelength and can therefore be used to probe smaller distance scales in order to resolve small scale structure. Also, higher energy collisions make it possible to produce and study the properties of heavier particles in the lab. In addition to high energies, high intensity beams can be used to discover and study ultra rare processes.

Major progress has been made in this field in the last 50 years toward composing a "standard model" (SM) of particle physics. Although this model is capable of describing nearly all observed phenomena, there are many questions left to answer. For example, in the SM the particles are allowed to carry mass due to the Higgs mechanism. In this model, masses are generated through the mechanism of spontaneous symmetry breaking of the electroweak force by the Higgs field. In addition to the field, the theory requires a massive particle called the Higgs boson, which has yet to be discovered. The Tevatron experiments at Fermilab have searched for and achieved unprecedented sensitivity to the Higgs boson. Over the last few years, I have made important contributions to the search for a low mass Higgs boson in the $\ell\nu b\bar{b}$ channel. The full Tevatron dataset could be greater than $10 fb^{-1}$, more than twice what has been collected so far. With this dataset, and improvements to analysis technique, the Tevatron has a significant chance of finding evidence for a low mass Higgs boson. I currently serve as the convener of the $Wh \rightarrow \ell\nu b\bar{b}$ analysis group and I plan to lead the effort to add analysis improvements in order to increase the probability that we will see the first signs of the Higgs boson at the Tevatron. This is my primary short-term research plan.

Even if the Higgs boson is discovered, questions still remain. Theoretical issues prevent the SM from being useful beyond the energy scale of a few TeV without some extension. There is also more direct evidence that the SM of particle physics is not complete. Astronomers observe an unknown source of matter through observations of galaxies and clusters of galaxies that cannot be explained by any known physics phenomena. It is possible that the particles making up this matter could be produced via the collisions of high energy particles. It is also possible that the effects of the interactions of these particles could cause deviations from the rates expected for SM processes, therefore yielding indirect evidence of their existence.

Undiscovered particles may exist just outside the energy reach of planned collider experiments. In this case, it may be possible to infer their existence by observing processes that occur at a higher rate than that predicted by the SM. I have recently become involved with R&D efforts for the mu2e experiment, an approved experiment that will search for the conversion of a muon into an electron in the presence of a nucleus. This process is extremely rare in the SM, but many extensions to the SM include charged lepton flavor violating interactions that would force this process to occur at a much higher rate. For example, many supersymmetric theories could provide a candidate for the mysterious dark matter, but also include lepton flavor violating interactions that could lead to a signal in the mu2e experiment. An observation of this reaction would be an absolute sign of physics beyond the SM! The mu2e experiment will be sensitive to models with energy scales far beyond that which can be produced at colliders like the Tevatron and the LHC.

Extremely interesting questions also remain in neutrino physics. Fermilab has plans for an intense proton source, called Project X, which will provide beam for multiple experiments designed to answer many of the open questions. Long baseline neutrino oscillation experiments will take advantage of an intense beam of neutrinos to take neutrino physics to a new level of precision. The NOνA experiment, for example, will search for evidence of muon to electron neutrino oscillations. This experiment could provide a measurement of the last unknown mixing angle, θ_{13}, observe matter/anti-matter asymmetries in neutrinos, and resolve the neutrino mass hierarchy.

In order to insure the long term success of particle physics in the United States, there must be a vibrant domestic research program. Although the Tevatron program will end in the next few years, I plan to continue to support US efforts in particle physics through the experiments at Fermilab related to Project X. I hope to use the contacts I have developed at Fermilab during my employment there to facilitate involvement in these experiments. My medium to long term research plan includes contributing to R&D efforts for mu2e and as my CDF work winds down I will consider joining another Project X experiment at Fermilab.

Due to the abundant possibility for discovery, these are truly exciting times to be a particle physicist! As a young physicist, I have had the pleasure of making contributions to several important measurements at the Tevatron. Now, I look forward to the future and the possibility of a major discovery! Once a signal that cannot be described by the SM is observed at the Tevatron, the LHC, or an experiment at the intensity frontier, theorists and experimentalists will share the difficult and exciting task of deciphering the implications of this discovery on the foundations of physics.

I look forward to this challenge!