Experimental High Energy Physics, Building Bridges

As I explained in my "Statement of Research and Professional Interest," my research in high energy physics has centered around an experimental understanding of the Higgs mechanism. This effort has required me to become adept in three general areas: 1) building and understanding complex devices used as particle detectors; 2) developing computer code for the statistical analysis of very large sets of data; 3) organizing and leading groups of physicists collaborating on a large project. Making connections to groups and areas of expertise outside of high energy physics has been the key to success of these three areas of experience.

The discovery of the Higgs particle would be a major step forward in our understanding of the fundamental laws of particle physics. Current experimental limits on the mass of this particle indicate that it could decay into a pair of b quarks if it were produced at the energies available at the Tevatron, and previously at LEP. Most programs to search for the Higgs boson take advantage of this experimental fact, by employing precision silicon microvertex detectors that are capable of measuring the characteristic decay signature of b quarks: a secondary vertex of two or more charged particles displaced from the primary collision point by a few millimeters. For the upgrade of CDF, we built the largest such device in operation. It has over 750,000 channels readout and digitized by custom electronics designed in large part part by LBL. I worked with the engineering department of LBL and vendors in Silicon Valley who did the microassembly of hybrid electronics mounted on beryllium oxide substrates. I was responsible for insuring the quality production of the 360 boards needed for the detector plus spares. This involved daily work with engineers, technicians, students and other physicists in our in house electronics lab at LBL, debugging the boards with probe stations and computers and developing testing procedures to allow for the rapid delivery of these parts to Fermilab where they were assembled into the final detector. I was able to deliver a critical-path item of electronics, but it was understanding how it fits into the larger scope of the experiment that allowed me to make key decisions during this project and the subsequent commissioning of the silicon detector as a whole. Without the collaboration of the engineering group, technicians and physicists, this very large scale project would not have been possible. And without this silicon detector, the physics program of CDF would have been substandard, instead of world class.

The production cross section of the Higgs signal we are looking for is of the order of 10 picobarns. The total $p\bar{p}$ cross section is several millibars, several orders of magnitude larger than our signal. Not only do we need a very precise and accurate silicon detector to reconstruct the signature of a Higgs boson decaying into b quarks and reject the very large background, but we needs lots of data–many millions of events. Because of the very large size of our data sample, it is impossible for a physicist to study each individual event collected. Instead we rely on code that searches through our massive datasets for statistically significant signals above a known or measured background. I developed C++ code that would measure the intrinsic resolution of the silicon detector, reconstruct the tracks of charged particles, identify jets formed by b quarks, and reconstruct Higgs particles. This code has to run efficiently and without crashing on terabytes of collected data, on farms of hundreds of CPUs. Except for the specific analysis of Higgs events, this code was used by the collaboration of hundreds of physicists.

This brings me to my last point. In order to work successfully in experimental high energy physics, I have had to be an active part of and build teams of collaborators. Because of the complexity of our experiments, working in isolation is not an effective solution to the problem. As a graduate student and young postdoc at CERN, I took an active role in all aspects of the search for the Higgs boson of the Standard Model. But just as important, as co-chair of the L3 collaboration's Higgs group, I successfully lead an international group of physicists in a combined effort to find the Higgs in many different search channels, and worked with other experiments on the LEP Higgs Working group to combine the results of all four LEP experiments in the most statistically significant search to date. As a postdoc on CDF at the Tevatron, I've continued to be an active member and leader of separate groups that optimized the performance of the silicon detector, commissioned software to identify b-jets, and finally to search for various possible Higgs signals. In each case, an effective team was the only way to achieve results in a timely fashion.

I have learned that building bridges is the best way to succeed in experimental high energy physics. We need good connections to electrical engineers, software developers, large computing resources, and the international community of physicists. As a faculty member at Purdue, I would be in a very good place to build such bridges.