
Frank DiMeo

UNPARALLELED EXPERIENCES

Undergraduates at LEPP and CHESS

VAIBHAV KUKREJA, A PHYSICS MAJOR, BEGAN UNDERGRADUATE RESEARCH IN THE SPRING OF HIS SOPHOMORE YEAR. HE SAYS THAT EVER SINCE HE WAS A CHILD, HE HAS HAD AN INTEREST IN SCIENCE AND IN HOW "PHYSICS AND PURE MATHEMATICS CAN EXPLAIN THE COMPLEX PROCESSES THAT OCCUR IN THE WORLD."

Every day many Cornell students walk down Campus and Tower Roads, and many take advantage of the athletic playing fields—Alumni Fields. Meanwhile, few students may know that under their shoes lies a world-renowned electron storage ring and high intensity x-ray source for conducting research in elementary-particle physics and x-ray science. For Vaibhav Kukreja '07, Nabil Iqbal '06, Harold Barnard '06, and Daniel Beer '06, these facilities have become a major part of their undergraduate experience.

The Laboratory for Elementary-Particle Physics (LEPP) and the Cornell High Energy Synchrotron Source (CHESS) deal with complex areas of particle physics and x-ray science that require constant regulation and innovation. Undergraduate research is an integral part of these research centers. Kukreja, Iqbal, Barnard, and Beer have conducted valuable research for the advancement of the centers, as well as for their own higher education and training.

Vaibhav Kukreja, a physics major, began undergraduate research in the spring of his sophomore year. He says that ever since he was a child, he has had an interest in science and in how "physics and pure mathematics can explain the complex processes that occur in the world." In spring 2005, he took a physics class in which his professor, Georg Hoffstaetter, Physics, mentioned an opportunity to work at the Wilson Lab on a NSF-funded prototype for a new x-ray source called the Energy Recovery Linac (ERL). Hoffstaetter remarks, "In class and in discussions after class, Vaibhav was one of the most alert and active students, and I was very pleased to hear about his interest in research."

The ERL accelerates particles so that they can produce extremely bright x-ray beams. Kukreja began working at LEPP on the cathode of the electron gun, where bunches of electrons are gathered and injected into the ERL. During the summer of

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Vaibhav Kukreja

KUKREJA BEGAN WORKING AT LEPP ON THE CATHODE OF THE ELECTRON GUN, WHERE BUNCHES OF ELECTRONS ARE GATHERED AND INJECTED INTO THE ERL.

2005, he worked with LEPP scientist Charles Sinclair to create a computer simulation of the cathode and its geometry. The cathode structure of the gun must be created out of a material that will minimize the potential for field emissions to prevent constant damage to the photocathode. The less distorted the electron beam, the better it will produce a smaller electron bunch for the smallest and brightest x-ray.

This research is central to LEPP's ability to create an efficient electron gun for the ERL. The cathode requires surfaces with low field emissions to handle the electrons that will be injected through the electron gun at 15 megavolts per meter—particularly in the future, when the electrons will need to be accelerated through an even greater field. Kukreja is working to test and treat various surface materials, applying and enhancing the model for electron field emission first developed in the 1930s.

Nabil Iqbal, a physics major, came from Bangladesh to Cornell with an interest in physics, which his parents had encouraged. Upon entering Cornell as a freshman, he began undergraduate research in physics. In the summer of 2004, he began working on a project for the Cornell Electron Storage Ring (CESR) aimed at improving the means of determining where the electron beam is located within the accelerator. Iqbal created a system of motors that can move a current-carrying wire around inside the beampipe, allowing the beam position monitors (BPMs) to determine the location of the electron beam within the cavity. This method was used to test newly developed algorithms for more accurate beam detection.

Working with LEPP researcher Matthias Liepe, Iqbal adapted this setup for use on the ERL. The electrons are shot out of the gun into the superconducting radio frequency (SRF) cavity, where they are further accelerated. The beam must be perfectly aligned with the electrical center of the SRF so that the quality of the beam is not compromised. To determine the location of the electrical center of the SRF, Iqbal used a string with metal beads based on the setup for the previous experiment. If the beads are in the center of the cavity, there is no distortion of the magnetic field, but as the beads move further away from the center, the distortion increases. The position that minimizes the distortion therefore corresponds to the electrical center of the cavity. The device Iqbal created allows LEPP to measure more accurately the position of the electrical axis.

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Nabil Iqbal

Like Iqbal, Harold Barnard, an applied and engineering physics major, was introduced to science at a young age by his parents, who were both physicists. He has always developed his technical abilities by building various hobby projects, including walking robots and full-sized wooden sailboats. From his high school studies and research experience in the fields of microfluidics, optics, and optical interferometry, Barnard gained an intense interest in math and the creative aspects of physics. By applying physics to develop new technology, he discovered the beauty of theoretical physics. With his diverse experience, Barnard was able to begin as a freshman working with Ernest Fontes, CHESS assistant director. Barnard views himself as a mechanical artist, using his knowledge to develop innovative technology. He was able to use his skills recently by working on the development of electronics and instrumentation for x-ray optics at CHESS.

CHESS uses intense x-ray beams, produced by the high energy electrons and positrons circulating in the CESR, for x-ray imaging and experimentation. The research in x-ray crystallography that takes place at CHESS is useful in the study of proteins and biological mechanisms. During the construction of the newest facility, G-line, Barnard helped to build electronics and hardware for the new x-ray optics room, called a "cave." He wired, tested, and installed nearly all the stepper motors for remote control of the precision optical elements. He then designed electronics for controlling the fluorescent screens that move into the x-ray beam at the touch of

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a button to provide a video image of the invisible spot. He also worked on tapered glass capillary optics for focused microbeam experiments.

It is imperative that researchers know the operating status of the CESR machine. During the summer of 2005, Daniel Beer helped update an old system called the "scoreboard," which displayed a line image of signals collected during operation of the particle accelerator and x-ray beamlines. The new scoreboard allows users at both CHESS and LEPP to view data from the monitoring system using the web.

Beer, an electrical and computer engineering major, has had a long-term interest in computers. He took a class in spring 2005 on microcontroller design, ECE 476, in which he partnered with CHESS technician Tony Lloyd for the final class project. After his positive experience in the class, Beer began working with Fontes to create the monitoring system for CHESS. The new scoreboard that Beer helped to develop extended the existing CHESS monitoring system by creating a software bridge that makes it possible for CHESS to read values from the LEPP accelerator monitoring system. Beer added improved visuals and options to the scoreboard, making it easier for users to customize the colors, charts, graphs, and signals of interest. A user can also zoom in to the specific time of a specific signal to read a precise measurement.

THE RESEARCH AT CHESS LED BARNARD TO FIND OTHER RESEARCH JOBS AT CORNELL AND SANDIA NATIONAL LABORATORIES IN NEW MEXICO, WHERE HE DISCOVERED HIS TRUE PASSION IN THE FIELD OF CONTROLLED FUSION AND PLASMA PHYSICS.

The work of these undergraduate researchers has been valuable in the operation, maintenance, and advancement of Wilson Lab. In addition to the benefits CHESS and LEPP receive from their research, the experiences have been worthwhile to the undergraduates in many ways. For both Barnard and Beer, the experience they gained while working for CHESS has helped them with pursuits outside of x-ray physics. The research at CHESS led Barnard to find other research jobs at Cornell and Sandia National Laboratories in New Mexico, where he discovered his true passion in the field of controlled fusion and plasma physics. He hopes to continue his studies in this field in graduate school. Beer pursues a master's degree in electrical and computer engineering and hopes to work in industry. As a result of his time working for CHESS, he now has more experience applying his studies to "real world problems." He says that, after collaborating with full-time employees there, "I feel I learned a lot about working with people in a professional environment."

Iqbal pursues an advanced degree in physics, where he hopes to study the theoretical side of physics. He nonetheless recognizes


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Daniel Beer

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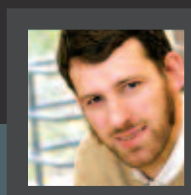
that it is important to conduct experiments and gain experience in a research setting. He explains that lab research is "totally different from experiences in your classes. It allows you to think independently and learn what science is really like." Similarly, the knowledge and experience Kukreja has gained so far by conducting undergraduate research has been crucial to his understanding of physics and his future goals. After his senior year at Cornell, Kukreja hopes to continue to study physics and mathematics in graduate school. In the classroom, physics majors study equations and concepts, but he says that this is not "the real picture." Before his research experience he had never "realized that such a simple process can have so many complexities. It is important to see where the material learned in the classroom is applied and how research can lead to modern advances."

CHESS and LEPP strongly encourage undergraduates to get involved in research at their facilities and in other areas of research on the Cornell campus. As Fontes explains, undergraduates are "special because they are testing the waters of scientific research and making personal decisions about going to graduate school or otherwise. I enjoy very much working with undergraduates, because they are still exploring options and are sincerely open to trying new things." With the wealth of professors and research organizations at Cornell, there are many opportunities for students to explore challenging but rewarding arenas of research.

Gillian Sarah Paul '08

GEORG HOFFSTAETTER, PHYSICS, ON UNDERGRADUATE RESEARCH



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An important part of research at Cornell is the faculty support of student researchers. Georg Hoffstaetter, Physics, is an excellent example of faculty dedicated to student research at all levels. Hoffstaetter is working on a prototype for the Energy Recovery Linac (ERL) at LEPP. He explains, "I believe that teaching on all levels is a very effective way to have a positive influence on the physics community."

In 2003 Hoffstaetter initiated a program at LEPP that provides K–12 students with opportunities to learn about particle physics through the Ithaca Learning Web. The program also grants high school students internship opportunities to explore their interests and talents, while being exposed to careers involving particle accelerators. So far, Hoffstaetter has advised three high school students from the program; two have since been accepted into Cornell's class of 2008.

In addition to his work with younger students, Hoffstaetter has made it a priority to work with undergraduates. Five were sponsored through NSF's Research Experience for Undergraduates (REU) program. He explains, "Cornell has an obligation to provide the most beneficial undergraduate experience to its students. For physics majors, this means that they have to be equipped with the skills they need to perform well during graduate school in the sciences or in an industrial laboratory."

Hoffstaetter highlights four reasons why an undergraduate research experience is important:

01: It gives students the opportunity to discover the direction that their graduate education should take.

02: It teaches technical as well as social laboratory skills that can be very beneficial in graduate school and industrial laboratories.

03: It can significantly enrich classwork by showing how abstract subjects that are taught in class have practical relevance in the laboratory.

04: It leads students in a research direction that a faculty member intends to promote.

He recommends that undergraduates interested in research choose their research directions thoughtfully. Hoffstaetter encourages students to talk to professors and visit seminars and group meetings before deciding which research experience to pursue, because "this is often a choice that shapes interest and expertise for graduate work and can thus have a far greater impact on a student's life path than initially imagined."

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