The Photon:
Spotlight

On Alumnus Patrick Connolly

Applying physics to neurosurgery

The physics-trained mind is primed for substantive inquiry, so it is well suited to advance the knowledge of our young specialty.

In January 1991, I went to Chris Lobb's office looking for an experiment to do, on the advice of Ellen Williams. Chris asked me about fixing things around the house, vacuum cleaners, cars, etc., and I said I knew how to solder. That was the beginning. We set to work on a project that culminated in a Phys Rev B Rapid Communication in 1994. My first exposure to physics in action was most favorable.

While I loved physics, I decided that I really wasn't smart enough to be a good physicist. That's how I came around to medicine. (Don't tell med school interviewers that kind of stuff.) After I graduated, I filled the pre-med requirements and continued in Chris's lab until June 1992. I thought all labs were like his, but I've come to learn that that concentration of talent in the Superconductivity Center was really unusual.

In October 1992, I came to work for a physicist named Russ McCally at APL. Again, I lucked out and got involved with a ridiculously talented group of individuals at APL and at Hopkins' Wilmer Eye Institute. We contributed to the pre-clinical and clinical development of the excimer laser, now used to do refractive eye surgery. We also ran experiments to elucidate basic biophysical properties of the cornea. This was a perfect bridge from physics into medicine.

In physics, mathematics is applied to solving problems. In medicine, judgment is usually the tool of choice. My physics education promotes rigor and circumspection in the daily application of clinical judgment. I graduated from medical school in 1998 and am now in my fourth year of training in neurosurgery. The physics-trained mind is primed for substantive inquiry, so it is well suited to advance the knowledge of our young specialty. The central nervous system is a complex and fragile three-dimensional structure that is difficult to image and access. Every step neurosurgeons take to render neurosurgery less invasive and more accurate means a safer (and sometimes more effective) solution to a patient's clinical problem.

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About Experimental Nuclear Physics

Professor Elizabeth J. Beise is a member of the Experimental Nuclear Physics Group at the University of Maryland

New ways of thinking may yield exciting results

by Elizabeth J. Beise
Professor of Physics

"Nuclear physics as a science is in an exciting period in which new ideas and new accelerators are providing unforeseen results and changing conventional thinking."

Nuclear physics is the study of the strong interaction between the fundamental constituents of matter, and how they combine together to make the nuclei of the atoms in the periodic table. Decades of experimental and theoretical work studying the shapes, charge distributions and excited states of nuclei have given us the ability to predict many of their properties, and they are well described as a collection of neutrons and protons bound together by the exchange of a pion. But this is not the end of the story. Decades of research in particle physics has also told us that the neutrons and protons that make up nuclei are not themselves the fundamental building blocks of matter, but are instead made of pointlike particles called quarks, that bind to each other by exchanging energy in the form of "glue". The fundamental theory that describes the interaction of quarks and gluons is called Quantum Chromodynamics, or QCD, and the property that describes how particles respond to the strong force is called color. Color is to QCD like charge is to electromagnetism.

The strong force, as described by QCD, has a few unique and mysterious properties compared with the other forces of nature that make it both interesting but at the same time very difficult to study quantitatively. One property, called confinement, means that quarks never appear by themselves, but are always confined either to quark-antiquark pairs (like a pion) or 3-quark groups (like a proton), each with a different color (while electromagnetic charge can be of two types, + or -, color can be any of three types, referred to as red, green or blue). Confinement is the reason why it does not seem possible to find a free quark. Another property, called asymptotic freedom, means that when the quarks are moving very fast or when we are looking at very short distance scales, they hardly interact with each other, whereas when they are not moving so fast or when we are looking over larger distances, such as about the size of a proton (10?15 m), they interact very strongly. So the QCD of high energy physics looks somewhat different than the QCD of nuclear physics, and it is still a theoretical challenge to connect these two energy/distance scales.

These mysterious properties of QCD make the study of the structure of the simplest nucleus, that of the hydrogen atom which is just a single proton, one of the most compelling avenues of research in modern nuclear physics. Also compelling is how we go from the quark-gluon description, obviously necessary to describe a single proton but not yet very successful in describing any other nuclei, to the picture of nuclei that seems to work so well, protons and neutrons exchanging pions. The proton has been studied for many years, particularly in pioneering experiments at SLAC in the 1970's, but new tools, both experimental and theoretical, have made the possibility of tremendous progress in understanding the proton a realistic goal.

One of the best ways to study the properties of a proton is to put it under a microscope, only the microscope has to be able to resolve distances much smaller than the wavelength of visible light. This can be achieved using an electron beam. Electrons can interact with protons (or quarks) through the (relatively weak) electromagnetic force (or the weak force), but not through the strong force, so they can scatter from a proton and leave it rather undisturbed. This makes it possible to study in detail its properties such as its charge distribution, its magnetic moment, its response to external electric and magnetic fields, and its spin, all of which ultimately arise from the underlying quarks and the sea of gluons and quark-antiquark pairs that make up most of the proton's mass.

The Experimental Nuclear Physics group at Maryland is involved in a variety of experiments at the newly built Thomas Jefferson National Accelerator (or "Jefferson Lab"), which began delivering its first electron beams in 1995. Jefferson Lab is a 6 GeV electron accelerator that produces a continuous (CW) beam of highly polarized electrons by recirculating them through two superconducting linear accelerators. The intensity of the beam is 100 to 1000 times higher than was available to experimenters at SLAC in the early days, and the CW nature of the beam makes it possible to detect scattered particles in coincidence with very high efficiency. Advances in laser technology and the development of new materials makes it possible to make beams that are highly polarized as well.

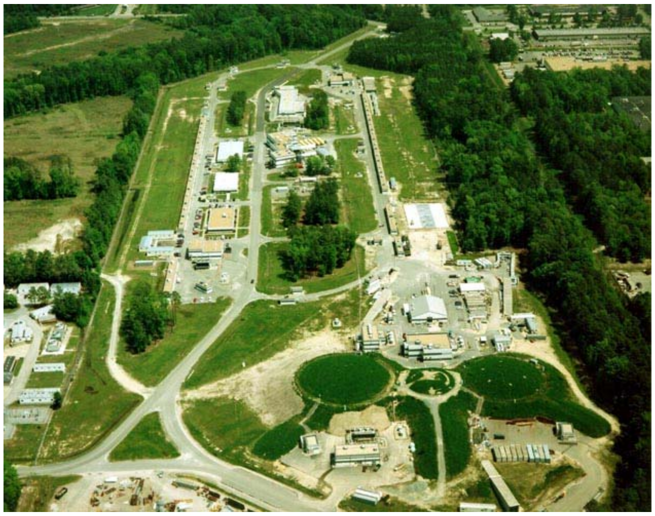


Figure 1: Arial shot of JLAB

In one recent experiment, which involved Profs. Jim Kelly and George Chang, the ratio of the proton's charge to magnetism was measured over a range of momentum transfer (larger momentum transfer means shorter distances), with very high precision using high resolution spectrometers in Jlab's Hall A and polarization techniques. These new data, which are much more precise than the older data sets from SLAC and DESY, seem to show that the proton's charge distribution has a bit of a hole in the center: it drops off much faster at smaller distances than the proton's magnetism. At present these data cannot be explained theoretically.

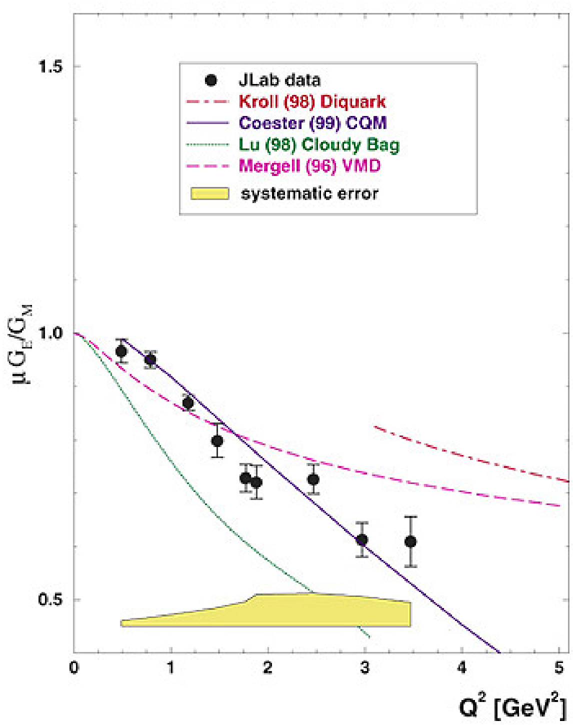


Figure 2a: Simplified GEP/GMP data.

Another major activity of our group is to use the weak interaction to learn about how strange quarks might contribute to the proton's charge and magnetism. The proton and neutron have two components to their structure, they each have three light up and down quarks, and then additionally have a "sea" of quark-antiquark pairs that disappear and reappear, sometimes annihilating each other to form gluons. The possibility of studying the contributions of strange quarks in the proton is unique because strange quarks come only from this quark-antiquark sea. The weak interaction, because of its violation of parity, or mirror symmetry, gives us another kind of microscope such that when combined with electromagnetic data, these strange quark contributions can be uniquely identified.

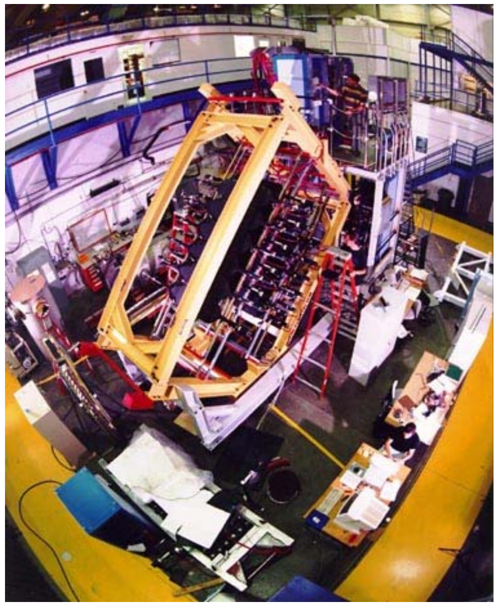


Figure 2b: A detector package in one of the two the Hall A spectrometers.

Profs. Betsy Beise and Phil Roos, along with senior scientist Dr. Herbert Breuer, are major contributors to the development of a new detector system, called "G0", that will use parity violating electron scattering at JLab to precisely map the contributions of strange quarks to the proton's charge and magnetism. The G0 apparatus consists of a superconducting toroidal magnet with an array of scintillators surrounding it to detect and count protons ejected from liquid hydrogen target at the center of the magnet after it is struck with the polarized electron beam. Prof. Roos took charge of construction of the North American contribution to the detector system, and Prof. Beise both contributed to the hydrogen target development and is managing the computation effort for the upcoming experiment, which will start taking data in 2003. Maryland graduate student Jianglai Liu will work on the first run for his Ph.D. thesis. The full program will take about five years.

These projects are a few examples of a broad array of experiments that, when taken together, will give us a much more detailed and comprehensive picture of the structure of the protons and neutrons that make up the world around us and help us understand the force that holds them together.

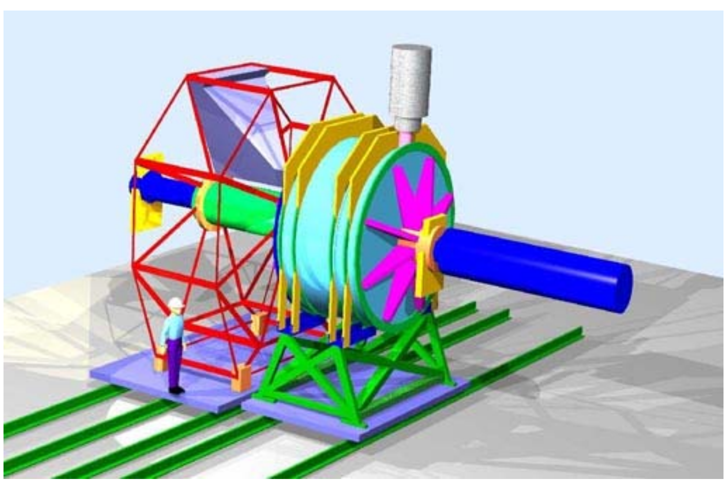
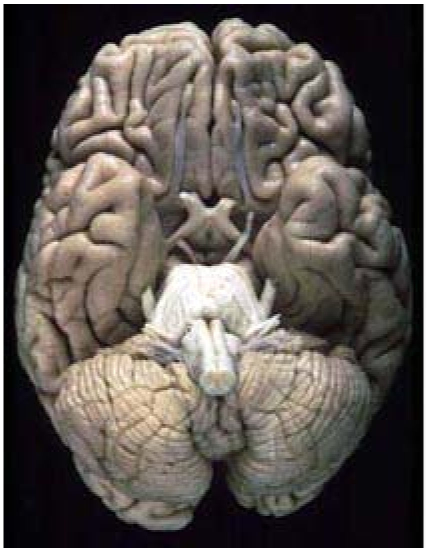
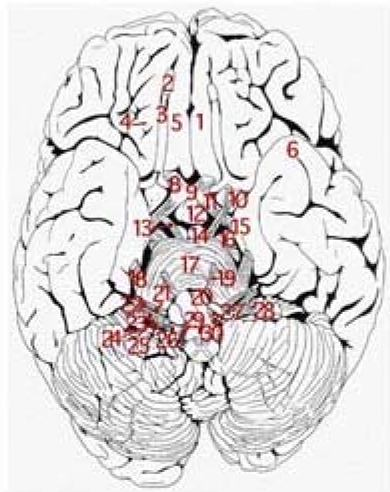


Figure 3a: Cartoon of the G0 apparatus.

Figure 3b: Two detectors being installed in the support frame (two-octants.jpg).





Neurosurgeons are experts in surgery on the brain or other nerve tissue.

Whether it aids in exposing the essence of a problem in critical care or clarifies the approach and implication of a laboratory problem, a physics education underpins the daily judgment and intuition of medicine with an analytical rigor.

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