Quantum Leap 2013

University of South Carolina
Department of Physics and Astronomy

A New Face

Dr. Vincent E. Guiseppe joined our department this semester. Dr. Guiseppe received his Ph.D. from the University of Maine and then was a Post Doctoral Fellow in the Physics Division at the Los Alamos National Laboratory—a highly competitive position for which he was selected because of his Ph.D. research experience in the sources of environmental radioactive background. In 2009 Vince joined the faculty of the University of South Dakota where he taught a variety of physics courses. Vince's research is in the area of particle astrophysics and it funded by a grant from the Office of Nuclear Research in the Department of Energy. He is currently one of the task leaders for the MAJORANA Demonstrator Project, a 21-million dollar cooperative initiative funded jointly by the Department of Energy and the National Science Foundation, and which is being installed at the Sanford Underground Research Facility (SURF) in Lead, South Dakota.

Vince is joining the Particle Astrophysics Group that includes Frank Avignone, Richard Creswick, Carl Rosenfeld and Jeffrey Wilson. This group is described elsewhere in this volume; however, for this section we are interested in Neutrino physics, searches for Cold Dark Matter, and searches for exotic particles such as axions. For some years now, the USC group has been involved in the development of low-background experiments that search for double beta decay with no emission of neutrinos ($0\nu2\beta$-decay). For this to occur, neutrinos must have mass and must be their own antiparticles. The observation of the $0\nu2\beta$ decay rate is one of the few measurements that can determine all the neutrino masses. This is a very important experiment that has been singled out by the agencies as a high priority. Vince has been involved in the MAJORANA Demonstrator Experiment since he moved to Los Alamos. In addition to extending our understanding of $0\nu2\beta$-decay in germanium, the Demonstrator is an R&D project to determine the best technology to use in a very large (ton-scale) experiment.

In his own words: "I am an active collaborator in the MAJORANA neutrino-less double-beta decay experiment, which is an experiment to study the neutrino through a rare neutrino-less double-beta decay process and observe dark matter interactions in an ultra-low background environment. My current involvement in MAJORANA is significant as an institutional representative and recent chair of the MAJORANA Executive Council and as a task leader managing the shielding systems. I serve on a talk assignment committee and participate in many of the experiment's working groups including the simulation and analysis, detector, material and assay, and engineering groups.

"In addition to contributing to the design and construction of MAJORANA, I have been studying potential backgrounds important to MAJORANA and other underground rare event searches. Even though it will be conducted underground, neutron-induced and radon-generated radiation contributes backgrounds to an experiment like MAJORANA. I have been studying the deposition and desorption of radon daughters on surfaces, neutron inelastic scattering in detector and shielding materials, cosmogenic activation of detectors materials, and interactions of alpha particles in detectors. I have several years of experience working with HPGe detectors and their data acquisition and cryogenic systems, as well as refurbishment and annealing of the detectors."

University of South Carolina

Message From the Chair

Prof. Milind Purohit, Chair

It's a pleasure to write this column for the first time. After our former chair, Prof. Chaden Djalali, left for the University of Iowa as Dean, we were served for a year by interim chair Prof. Varsha Kulkarni, and I'd like to thank her for her service to the department.

Chaden was joking about Iowa being named the top party school by the U.S. News and World Report, but we were more gratified to see that the University of South Carolina did not make the list of top 20 in that category! More importantly, our Provost recently brought up a series of figures indicating that the University has climbed into the league of top universities in the nation. The incoming Honors College class average SAT score is 1432. The enrollment at USC has climbed to almost 5000 incoming freshmen. The one-year and six-year graduation rates are at all-time highs. We know we are attracting more out-of-state students than ever.

Of course, physics continues to attract people from all over the world, including top faculty as well as top students. Our two new faculty this year are Prof. Yanwen Wu (who comes after a year's deferrment) and Prof. Vincent Guiseppe. Prof. Wu will be working, among other topics, on the optics of nanoparticles, while Prof. Guiseppe will join Prof. Avignone's effort on pinning down the nature of neutrinos: are they Majorana or Dirac particles?

The influx of new blood cannot come at a more opportune time. Federal funding is on a decline for all of science, with the National Science Foundation poised to award 1000 fewer grants this year thanks to federal budget sequestration that went into effect on March 1, 2013. During the past year, our department's research funding has dropped back to what it was in 2011, and we are very concerned about the impact on research and even departmental funding. At the same time, we are delighted that some of our young researchers are securing significant new funding in this dismal climate for science. Assistant Professors Scott Crittenden, Yuriy Pershin, and Matthias Schindler have all done very well in this respect, which bodes well for our future. Congratulations to all three!

Our graduate student body has seen the annual turnover, and we're happy that five of our incoming class have secured fellowships! Graduate students Shu Yan and Nahid Shayesteh Moghaddam received the best research and teaching awards this year. Our community outreach efforts have continued unabated, with Prof. Wilson and others teaching area physics teachers in the summer, interacting with thousands of high school students during the R. L. Childers Midway Physics Day at the S.C. State Fair, and many professors hosting local high school students during the summer. We are also delighted that we have been joined this year by Mandy Davis, our new Graduate Student Coordinator, who has taken over from Dee Brown. Welcome, Mandy!

Even more good news this past year has arrived in the form of accomplishments and awards for our faculty. Prof. Ralf Gothe was awarded the Russell Research Award by the University. Associate Prof. Thomas Crawford was named a USC Rising Star for 2013. The extramural awards front has been equally exciting. Prof. Milind Kunchur was named an APS Fellow, and our retired Distinguished Professor Emeritus Dr. Horacio Farach received Argentina's highest civilian honor, the "Notable Argentinians" award from the Argentine Congress on August 23, 2013. Prof. Richard Creswick attended the ceremony and the college sent Dean Robert Thunell as a USC representative as well. Finally, Assistant Prof. Matthias Schindler won a 5-Year DOE Early Career Research Program Award, as well as the Few Body Physics Award in Theoretical Physics. We are delighted with this surfeit of good news, immensely proud of our faculty achievements, and look forward to a bright future for the department!

Staff News

Our staff has been as busy as ever over the last year. In late April, Dee Brown (Graduate Program Coordinator) decided to move closer to her family and accepted a job at Clemson University. Although we don't like the color orange around here, we're happy that she and her daughter, Ryleigh, are doing well. Dee is even still wearing her garnet and black!

After Dee's departure, Mandy Davis joined our department on August 1 to fill the position. Mandy previously worked in the USC Police Department. She holds a Master's degree in Art History.

Speaking of art, we are happy to report that Evelyn Wong (Administrative Assistant) has been very active in the art world lately. She has participated in several juried shows and events over the last year and has also been asked to exhibit her artwork in a group show December 2013. If you are in the Columbia area at that time, be sure to check it out at S&S Art Supply on Main Street.

James Clawson (Laboratory Manager) and his wife, Staci, are expecting a new addition to their family in February 2014. Their son, Daniel, is looking forward to being a big brother.

Over the summer, Beth Powell (Administrative Coordinator) took on a new adventure as foster mom to baby squirrels for Carolina Wildlife Care. So far, she has helped raise five babies until they were big enough to go back to the center to continue their rehabilitation to the wild.

Evelyn, James, Beth, Lisa Saxon (Business Manager), and Robert Sproul (Factotum Emeritus) were very happy to welcome Milind Purohit as the new Chair of the department beginning July 1. Milind has settled in quickly, and we look forward to working with him in the coming years.

Mandy Davis

We hope you have enjoyed catching up with our department through this newsletter, and we look forward to receiving news from you, too!

News from The Director of Graduate Studies

By Richard Creswick

New Students

This year's incoming class is quite diverse, with students from Nepal, Iran, and China as well as the US. Of the nine new students, more than half are women, which is a first for our department!

Four of our incoming students are GAANN (Graduate Assistance in Areas of National Need) Fellows. The GAANN fellowship is funded by the US Department of Education and provides support for eligible students for three years. Ken Stephenson, who started in Fall 2013 and is working with Prof. Thomas Crawford, has received a National Physical Sciences Consortium Fellowship. Ken is the first NPSC fellow at USC.

We also have several "provisional" students in the USC English Program for Internationals from Ecuador and Iraq. These students will spend a year perfecting their English before they begin their graduate studies in our department.

Ph.D. Recipients

Lewis Graham received his Ph.D. in December 2012 with Professor Ralf Gothe in the Experimental Nuclear Physics Group. Katarina Leila Mizouni received her Ph.D. in August 2013. Leila worked with Frank Avignone in the Astroparticle Physics Group.

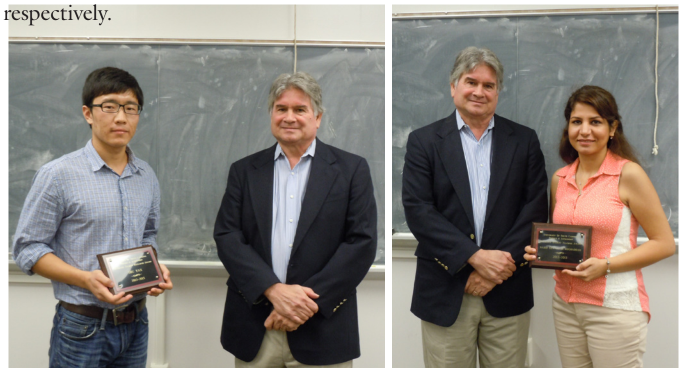
M.S. Recipients

Rasha Kamand received her Master's degree for her research with Professor Matthias Schindler. Rasha will continue in our graduate program to work towards her Ph.D.

Scholarships and Awards Recipients

Shu Yan received the Graduate Research Award and Nahid Shayesteh Modghaddam received the Graduate Teaching Award for 2012-2013.

Hongyue Duyang received the University's Research Association Award to support his research at Fermi Lab. Evan Phelps and Ye Tian have been awarded Jefferson Lab Graduate fellowships for 2012-2013 and 2013-2014, respectively.



Prof. Richard Creswick with Shu Yan, who received the Graduate Research Award, and Nahid Shayesteh Modghaddam, who received the Graduate Teaching Award for 2012-2013.

News from the Director of Undergraduate Studies

By Jeffrey Wilson

Our biggest news this year is the creation of the Dr. Edwin R. and Mrs. Elizabeth F. Jones Endowed Scholarship. This scholarship will be awarded to a Junior or Senior majoring in Physics, Chemistry, or Mathematics who received their high school diploma from a South Carolina high school or was home schooled in South Carolina. Dr. Jones is currently an Emeritus Professor in Physics and Astronomy. He served as our Undergraduate Director for many years and helped forge strong relationships with local high schools. He and Professor Richard Childers developed the Midway Physics Day event in 1996, which is still hosted by the Department and going strong as the R.L. Childers Midway Physics Day at the S.C. State Fair. We owe him a large debt of gratitude for all he has done and continues to do for science in South Carolina.

Prof. Jeffrey Wilson speaks to high school teachers as they arrive at the S.C. State Fair for Midway Physics Day.

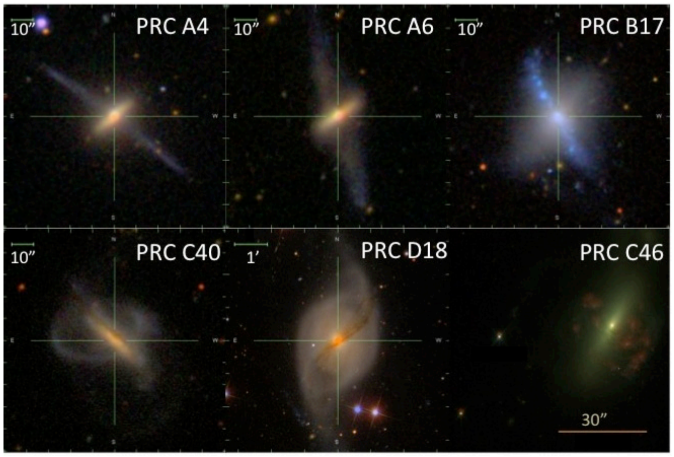
Other exciting news: The proposal that Professor Brett Altschul submitted last year to host a National Science Foundation Research Experience for Undergraduates (REU) in our department was funded. We will host our first REU experience next summer with space for about ten students. In addition to strengthening our undergraduate research, we hope that this can also be a huge recruiting tool for our graduate program.

The incoming freshman class this year is the largest on record. This has trickled down to produce enrollments in our introductory courses that are also the largest we have ever experienced—including our Physics Majors sections. We are waiting to see if this increase shows up in our upper division in the coming years.

From the Spring 2013 Awards Ceremony, Physics award winners were Han Lin, who received the College of Arts & Sciences Rising Senior Award; and William Cole Franks, who was awarded the Nina and Frank Avignone Fellowship. In addition to the Physics awards, several physics students won awards from other departments: William Cole Franks was awarded the National Defense Science & Engineering Graduate Fellowship as well as the Outstanding Undergraduate Student in Mathematics Award; Luis Miguel Suarez, Reid Monroe Harris, and William Cole Franks were awarded the Jeong S. Yang Award for Excellence in Undergraduate Mathematics.

Astronomy

Long Ago, in Galaxies Far Away…



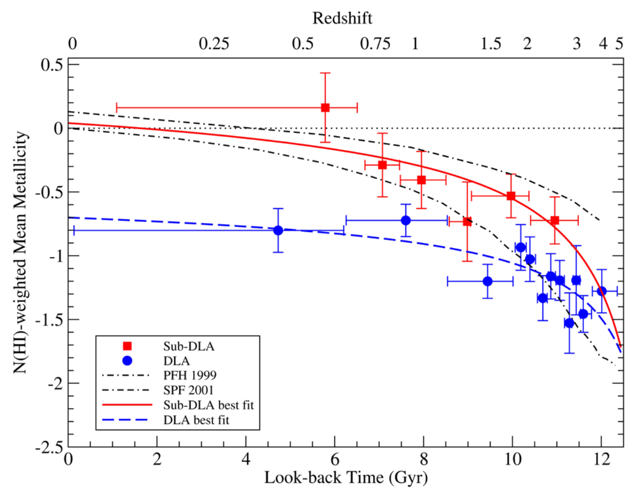
The speed of light is very high by all standards (about 186,000 miles per second), but it is still finite. For most day-to-day phenomena on the Earth, light signals appear to travel instantaneously, but the light travel time becomes substantial on large distance scales. The further away we look in the universe, the longer the light's journey to the Earth—and thus the further back in time we get to glimpse the universe! Light from the Moon reaches us in only about 1.3 seconds, while light from the Sun reaches us in about 8 minutes. Likewise, the light coming from objects billions of light years away gives us a glimpse of those objects when the universe was only a fraction of its present age!

What were galaxies like in this youthful past of the universe? How did the history of star formation in these galaxies unfold with time? How did our Galaxy (and others like it) reach the current composition of different chemical elements? How do galaxies interact with their surroundings? These are some of the questions that the USC astronomy team and their collaborators are working on.

Our work is a little bit like archaeology, but our "digging tools" consist of telescopes, cameras, and spectrographs. We use optical, infrared, ultraviolet, and X-ray observations to investigate the evolution of galaxies and the intergalactic matter over the past twelve billion years (about 90% of the age of the universe). In order to observe these distant objects, we use various state-of-the-art telescopes around the world, such as the Gemini and Keck telescopes in Hawaii, the Large Binocular Telescope in Arizona, and the Magellan Clay telescope and European Southern Observatory's Very Large Telescope in Chile. We have also been using NASA's Hubble, Spitzer, Chandra Space Telescopes, and the Herschel Space Telescope operated by the European Space Agency and NASA. Our work is funded by the National Science Foundation (NSF) and NASA.

Recently, we discovered one of the most gas-rich galaxies detected to date via its strong absorption line signatures on the spectrum of a background quasar. This galaxy allowed us to make the first detections in distant galaxies of Cu as well as fine-structure lines of Si+. To "mine" rare elements in more gas-rich galaxies, we have recently been awarded observing time on the Keck telescope in Hawaii (the largest existing optical telescope in the world). We have also discovered that the interstellar silicate dust in distant galaxies may be crystalline, in sharp contrast to the amorphous silicate dust found in the Milky Way! We have recently started to study the structure of a rare class of galaxies known as polar ring galaxies that can help to map the distribution of dark matter in galaxies. In addition, we have recently embarked on a collaboration with several theoretical physicists to obtain improved spectral diagnostics of heavy elements at high redshift through modeling. Our research resulted in five publications within the past academic year, with four other papers currently under review, and more papers in preparation. Several members of our team gave presentations at national and international institutions and conferences.

Graduate student Debopam Som published his first first-author paper, which just appeared in the Monthly Notices of the Royal Astronomical Society, the premier British publication in Astrophysics. Debopam has also been an important coauthor on several other publications, and will be graduating during the 2013-2014 academic year. Graduate student Sean Morrison is working on far-infrared observations of molecules at high redshifts obtained with the Herschel Space Observatory. Some of his work was presented at a NASA-sponsored conference on Molecular Spectroscopy in the Era of Far-IR Astronomy. A new addition to our group is graduate student Francie Cashman, who has just joined our department. Francie is beginning to assist with our work on improving atomic data needed for astrophysical



spectroscopy, and the associated modeling of the spectra of distant galaxies. Post-doctoral fellow Dr. Monique Aller is continuing studies of interstellar dust in distant galaxies. Using infrared spectra obtained with the Spitzer Space Telescope, we have been making the first detections of silicate dust grains in distant galaxies. Undergraduate students Heath Smith and Kyle Lackey have been analyzing images of the rare but fascinating polar ring galaxies with the Gemini and Spitzer telescopes. In a study with NASA's Chandra X-ray Observatory, Prof. Varsha Kulkarni, along with Prof. Geoge Chartas from College of Charleston (who is also an adjunct faculty at USC) and CofC undergraduate Abigail Asper, found tentative evidence that some types of absorber galaxies may host active galaxies fueled by super-massive black holes. Bryan Pugh, an undergraduate student from South Carolina State University, also worked with our team during Summer 2013.

In other news, Ms. Thusheeta Sivayogan joined our department as an instructor of Astronomy and Physics. Ms. Sivayogan, Dr. Dan Overcash, and Mr. Alex Mowery continued outreach efforts at the Melton Memorial Observatory, where public nights are held on all clear Monday nights. Our other outreach activities in the past year included popular talks at the Midlands Astronomy Club and the Augusta Astronomy Club, as well interviews with local newspapers and TV stations. As Director of the Astronomy Center, Dr. Soheila Gharanfoli continued her excellent undergraduate teaching work.

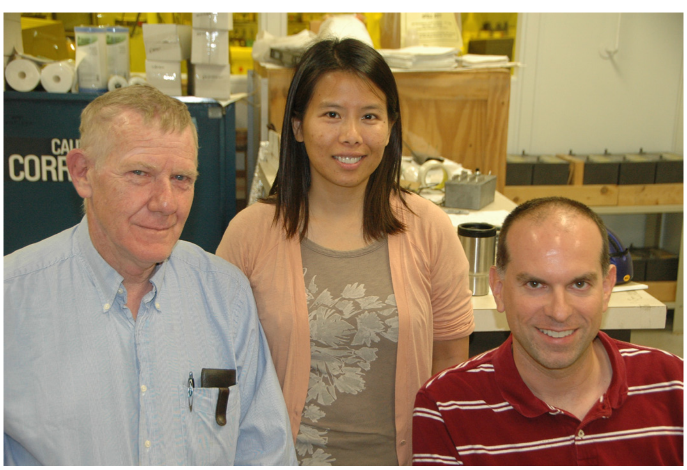
Additionally, our department hosted the Fall 2012 meeting of the Southern Atlantic Coast Section of the American Association of Physics Teachers. Prof. Kulkarni will be organizing the next annual Meeting of Astronomers in South Carolina at USC in Spring 2014.

To make a long story short, the Astronomy Group here at USC is having a great time digging up the many mysteries of galaxies far, far away!

Condensed Matter Group

P&A Smart State Center gets its chair back and goes "blue sky" for the future of Physics

Physics and Astronomy is home to the first Smart State Center created in South Carolina as part of the Centers of Economic Excellence (CoEE) Endowed Chairs Program. The Center, chaired by Palms Chair Prof. Richard A. Webb, is crewed by Profs. Thomas Crawford, Scott Crittenden, and Yanwen Wu on the experimental side, and Yaroslaw Bazaliy and Yuriy Pershin on the theory/computational side. The Smart State Center for Experimental Nanoscale Physics focuses on building new physical understanding of novel nanoscale materials through advanced experimental measurement. Materials systems currently being studied within the center include semiconducting nanowires and graphene, a collaboration between director Webb and Profs. Goutam Koley and Xiaodong Li in USC's electrical and mechanical engineering departments. Novel device properties of nanoscale systems are being investigated by Prof. Pershin, whose research has been cited more than 700 times during 2012. Profs. Crawford and Bazaliy both study magnetic nanomaterials for spintronics and nanomanufacturing, and Prof. Crittenden studies nanoscale surfaces and their modification with Scanning Probe Microscopy. Finally, the center's newest recruit, Prof. Yanwen Wu, has just arrived at USC. As soon as her lab is ready this fall, she will begin ultrafast optical experiments on nanoscale plasmonic hybrid structures. The Center continues to contribute to a developing knowledge economy in the state of South Carolina by attracting extramural funding, generating publications in peer reviewed journals, giving national and international invited talks, and placing students in permanent positions in South Carolina companies. The Center's first start-up company, MagAssemble, LLC (launched by Crawford), is in the process of securing funding to develop nanomanufactured coatings for optical materials and devices.

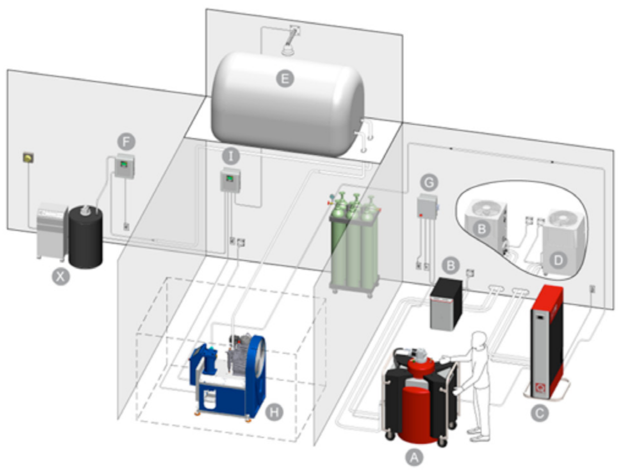


Prof. Webb (left), Prof. Wu (middle), Prof. Crawford (right)

Prof. Webb is Back!

Unfortunately, in May of 2012, while at home, Prof. Webb suffered a terrible fall. This fall landed him in the hospital and in physical therapy throughout Summer and Fall 2012. Webb is back at USC as of January 2013, and Crawford, who is serving as the center's first deputy director, is assisting him in managing the Center. Within the next year, the Center will be launching new programs aimed at attracting graduate students and helping the faculty here to achieve their research goals and develop new collaborative research projects, as well as launching a distinguished visitor program. During this past summer, Prof. Webb could be found working on the famous gold evaporator that "got him into the National Academy," or checking gas connections on the helium storage tanks for the new liquifier, i.e. in the lab!

A "Blue Sky" Project With the soaring cost of liquid helium and the loss of helium to outer space, the Center for Experimental Nanoscale Physics has ordered a helium liquifier and recovery plant with the goal of recovering and reusing the helium that enables our low-temperature and high magnetic field experiments. Arriving in late Fall 2013, the high-pressure recovery system consists of a big "gas bag" that collects helium boiled off during liquid transfers and daily operation, a compressor to store the collected gas in a bank of cylinders, and finally, a purifier/liquifier capable of producing more than 20 liters a day of liquid helium.



Helium Recovery System Diagram

Updates on Center Personnel

During spring 2013, Prof. Crawford was on sabbatical at Clemson University, and is now an adjunct faculty member of Clemson's Center for Optical Materials Science and Engineering Technologies (COMSET). COMSET students have visited our Smart State Center and used our Vibrating Sample Magnetometer to perform measurements on their samples. During this past summer Crawford hosted Prof. Jennifer Andrew of Florida-Materials Science, and was supported by an SEC travel grant to conduct research on multiferroic fibers in Crawford's lab at USC. Crawford, together with graduate student Longfei Ye, employed Crawford's "Pattern Transfer Nanomanufacturing" technology (patent pending) to build optical diffraction gratings entirely out of nanoparticles embedded in thin polymer films. These films are curved into the shape of a lens and can both focus and spectrally resolve visible light. Extremely inexpensive to manufacture, this technology could enable an entirely new approach to material manufacturing, centered here in South Carolina.

continued on next page

Prof. Yanwen Wu has been on leave working with Prof. Elaine Li's group at UT-Austin, on measurements of gold nanostructures and fundamental properties of epitaxially grown silver films. This collaboration has lead to a publication and pending submission in Nature Photonics. Prof. Bazaliy has an ongoing collaboration with Dr. Revaz Ramazashvili of Universite Paul Sabatier, Toulouse, France, on theories of spin torque dynamics in magnetic nanostructures.

Prof. Yuriy Pershin has developed foundations for a new type of computing device. By combining storage and computation in the same physical element, his technology, "Memcomputing", could be significantly faster than current computer architectures, enabling new applications and economic development. This work has been published in Nature Physics and received an Honorable Mention at USC Invent Event.

Prof. Scott Crittenden, working with postdoctoral associate Dr. Bharat Kumar, has developed the ability to measure the layer of organized ions that forms in aqueous solutions near any surface. The work, published in the journal Nanotechnology, will assist in developing "artificial" water at the surface of a material to enable the construction of new and robust biosensors for the detection of pathogens and toxins. Kumar has recently returned to India as an INSPIRE Assistant Professor at the Indian Institute of Technology at Kanpur, one of the most highly regarded universities in India, and has been replaced by postdoctoral research associate Dr. Andrea Gazzé.

Superconductivity and Sound

Professor Milind Kunchur's research group works in two areas: superconductivity, thin-films, and nanofabrication; and psychoacoustics, auditory-neurophysiology, and high-end audio. Ongoing experiments probe current-induced depairing and vortex explosion phenomena in superconductors. Recently, the new phenomenon of oscillatory magnetoresistance in superconducting transitions was discovered, but the theory for this effect remains a mystery at present. In October 2013, Prof. Kunchur reported this discovery during an invited talk for the NATO International Conference on Nanoscience and Engineering in Superconductivity that was held in Yalta, Ukraine.

In March 2013, Prof. Kunchur was awarded the certificate confirming him as a Fellow of the American Physical Society. In April 2013, the Office of the Provost at USC and President Harris Pastides also nominated him for the Council for Advancement and Support of Education (CASE) and Carnegie Foundation "U.S. Professors of the Year Award."

In 2013, three graduate students—Manlai Liang, Charles Dean, and Nahid Shayesteh Moghaddam—worked in Prof. Kunchur's group. Manlai Liang will defend his Ph.D. dissertation in December 2013. Four undergraduate students—Justin Putnam, Kevin Wood, Nate Moisson, and Elizabeth Minten—worked in Prof. Kunchur's group as well. Justin Putnam graduated in May 2013, with Prof. Kunchur as the director of his senior-year Honors College thesis titled, "High Fidelity Loudspeaker Design and Construction."

Nuclear Theory Group

Faculty members: Professors Fred Myhrer and Kuniharu Kubodera

The big news for the nuclear theory group is that Kuniharu will retire at the end of the fall semester 2013. Ever since Kuniharu joined our faculty in 1989 we have had a very fruitful and enjoyable collaboration resulting in many joint publications. We hope he will stay in touch with us as an active participant in our research projects. The group certainly can benefit from his knowledge and sound physics intuition in the coming years. It is our most sincere wish that Kuniharu will enjoy his retirement and keep up his activity as an excellent ballroom dancer and that he will cultivate his long-standing hobby on butterflies on which he is (almost) a professional expert!

During the Fall 2012 semester Prof. Myhrer was on sabbatical leave at the University of Adelaide, Australia where he actively worked on several different projects. One project concerned the question of how the magnetic moment of baryons and the related total baryon spin of 1/2 are distributed among the gyrating quarks in the baryons. Recent lattice simulations of how the strongly interacting quarks in baryons contribute to the total baryons' spin have produced results that we could compare to a quark model evaluation. The model results obtained indicate that even the orbital angular momentum of the heavy gyrating strange quarks are significant, and resulted in a Physical Review Letter publication.

Prof. Udit Raha is still active in our research group but has had to slow down due to his teaching duties at the Indian Institute of Technology Guwahati in Assam, India. We have completed work on muon capture in hydrogen including the radiative corrections, and the follow-up project on the muon capture on deuteron, on which Dr. Young-Ho Song and Prof. Vladimir Gudkov are also collaborating, will hopefully be completed this year. The capture rate of this latter reaction is currently being measured with unprecedented accuracy by the MuSun collaboration at the Paul-Scherrer Institute (PSI) in Switzerland. Our group is a member of the MuSun collaboration.

Dr. Saori Pastore joined our group in December 2012. She is actively working with her Argonne National Laboratory colleagues on electromagnetic structure and transitions in light nuclei. The renewed interest in these nuclear structure questions relies on the modern computing resources that allow for a microscopic description of nuclei in terms of nucleons interacting via two- and three-nucleon potentials. Within this framework, nuclear electromagnetic currents are also decomposed in many-body components, which are found to be crucial for a precise evaluation of electromagnetic observations. Pastore has also joined the USC group's effort in a project aimed at reexamining some long-standing questions regarding radiative corrections in nuclear processes.

It is encouraging and is a reflection of the international standing of our research group, that we have been solicited to contribute review articles for the International Journal of Modern Physics on pion production from nucleon-nucleon collision (2012) and this year (2013) on muon capture in hydrogen. Our group has investigated both topics for years. Prof. Myhrer has formed a collaboration with German and Russian scientists to further investigate inelastic and two-nucleon pion production reaction. As part of this collaborative research effort, Myhrer has spent weeks during the last three summers conducting research at the Ruhr University Bochum in Germany. This collaboration has made significant progress in the understanding of this reaction and one of the invited review articles mentioned above is being written together with two of the overseas collaborators.

Theoretical Physics Group

Faculty members: Brett Altschul, Vladimir Gudkov, Pawel Mazur, and Matthias Schindler

The Theory Group has had another active year.

For Matthias Schindler, it has been a particularly successful time. He received a grant from the Department of Energy's Early Career Research Program. The program is designed to support untenured junior faculty members who are making exceptional contributions to research, and the grants provide five years of funding.

Schindler's grant will support his research in the area of parity violation and related problems in few-body nuclear physics. This is currently an extremely active area of research, in which Vladimir Gudkov is also involved. The department's research in this area benefits greatly from relative proximity to and collaboration with the Spallation Neutron Source (SNS) at the Oak Ridge National Laboratory in Tennessee. The SNS produces high intensity neutron beams, which are used for applied physics and materials science experiments, and for fundamental studies of parity and time reversal invariance that Schindler and Gudkov are studying theoretically. The SNS is the world's premier location for neutron research, and Gudkov and Schindler are regular visitors to the Fundamental Neutron Physics Group at Oak Ridge.

Schindler's work in this area was also recognized with one of the inaugural Few-Body Systems awards from the European Research Committee on Few Body Problems in Physics (ERCFBP). Two awards are to be given every three years, to a theorist and an experimentalist, each early in their career, for work done in this area. The winners receive $1000, a free book from Elsevier Publishing, and the chance to give special invited talks at the ERCFBP's conference.

In addition to the award, Schindler published an invited review (coauthored with Roxanne Springer of Duke University) on "The Theory of Parity Violation in Few-Nucleon Systems" in Progress in Particle and Nuclear Physics.

Young-Ho Song, who worked with Gudkov for several years as a post-doctoral research associate, moved to a position as a principal research fellow at the Institute for Basic Science in South Korea in March 2013. The institute is an ambitious new enterprise, inaugurated by the South Korean government in 2012, aimed at promoting basic research in science, engineering, and related fields. Fundamental physics research, with emphases on particle, nuclear, and condensed matter theory, will be one of the primary focuses of the new institution, as it should continue to grow over the next four years.

Song worked extensively with Gudkov on fundamental symmetry problems in systems of three nucleons. They worked particularly on problems in neutron-deuteron scattering, looking at how parity and time reversal invariance violations could manifest themselves. The two kinds of symmetry breaking can occur simultaneously in particles with permanent electric dipole moments, and Gudkov and Song looked at this possibility in three-particle hydrogen and helium nuclei.

Brett Altschul has continued to work on fundamental symmetries as well, including Lorentz invariance (which encompasses rotational isotropy and the Lorentz boost symmetry of special relativity) and the combined discrete symmetry of CPT. While violations of symmetries such as P and T have been observed in the weak interactions, no physical breaking of Lorentz and CPT invariances has yet been seen.

Altschul's ongoing collaboration with the laser spectroscopy group at the Max Planck Institute for Quantum Optics in Garching, Germany (led by Nobel laureate Theodor Hänsch) came to fruition in 2013, with the publication of a paper in Physical Review Letters outlining the best atomic test of boost invariance for electrons. The results were based on studies of the two-photon 2S-1S transition in hydrogen, whose energy is known extremely precisely. Comparing the results from measurements taken at different times of year, when the entire Earth was moving with different speeds, produced the new constraints.

Rasha Kamand, a graduate student working with Schindler, completed an M.S. degree in 2013. Her thesis looked at the use of effective quantum field theory techniques to determine the cross section for a neutron-proton nuclear fusion reaction. This analysis was done in connection with the problem of Big Bang nucleosynthesis, through which the universe's first crop of heavier nuclei was formed. Kamand is currently continuing her research in the Ph.D. program in theoretical physics.

Prof. Matthias Schindler accepting the Few-Body Systems award.

Experimental Nuclear Physics Group

The experimental intermediate-energy nuclear physics group (ENPG) consists of three faculty members: Ralf Gothe, Yordanka Ilieva, and Steffen Strauch. Other members of our group include two postdoctoral researchers, Gleb Fedotov and Nicholas Zachariou; eleven graduate students, Tongtong Cao, Saptaparnee Chaudhuri, Colin Gleason, Gary Hollis, Hao Jiang, Yuqing Mao, Aneta Net, Evan Phelps, Ye Tian, Arjun Trivedi, and Nick Tyler; and many undergraduate students. Physics B.S. graduates, Rob Hedrick and Jesse Anderson, graduate student Rajshekar Sarkar, and undergraduate student James Thomason joined us in our detector construction effort. Additionally, we are excited to welcome new members in our group: graduate students, Colin Gleason, Aneta Net, and Nicholas Tyler; and undergraduate student, Cameron Nickle.

The study of the atom's nucleus and its constituents on the quark level is the core of our research. We are heading experiments at one of the flagship facilities for nuclear physics research in the U.S., the Thomas Jefferson National Accelerator Facility. We are also engaged in collaborative research at the J-PARC proton accelerator in Japan, the electron accelerator MAMI in Mainz, Germany, and the Paul Scherrer Institute (PSI) in Switzerland. Our studies focus on Quantum Chromodynamics and Nuclei and are recognized as U.S. nuclear science frontiers. The main questions our research addresses are: what is the internal landscape of the nucleon, how do the properties of strongly interacting particles change in the nuclear medium, what governs the transition of interacting quarks and gluons to pions and nucleons, and what is the nature of the nuclear force that binds quarks into protons and neutrons and nucleons into nuclei? In the past year, the members of our group presented our research and findings on these topics at 30 invited and contributed talks at national and international levels. This is a token of the international recognition of our group, as is the fact that we have published dozens of articles on our collaborative research.

The past year was full of events—changes, challenges, and rewarding experiences. We are delighted to share that Prof. Chaden Djalali has been appointed Dean of the College of Liberal Arts and Sciences at the University of Iowa (UI). While we are very proud and happy for Chaden, we are also sad to see him leave USC and the ENP group. Chaden has been with the group since 1989 and has been instrumental in the successful development of the group and its research. We wish him lots of luck and all the best in his new and prestigious position! Another big applause goes to Prof. Ralf Gothe who received the 2013 Russell Research Award in Science, Mathematics, and Engineering, the highest USC research recognition. Congratulations, Ralf! Kudos also to our Ph.D. students, Lewis Graham and Ye Tian! Lewis successfully defended his dissertation last December on the study of two-pion photoproduction off the deuteron and is now Director of Assessment at Morris College in Sumter, SC. Ye is the proud winner of a JSA/JLab Graduate Fellowship for the 2013 – 2014 academic year.

Among our key achievements in the past year is the publication of a review article, Studies of Nucleon Resonance Structure in Exclusive Meson Electroproduction, which was initiated and chief-edited by our group. The article is a natural culmination of our efforts to produce results, propose next generation experiments, and to build a network of physicists working on the evolution of confined towards asymptotically free quarks. We have also published a letter describing our cross-section data for two-body photodisintegration of helium-3 at a center-of-mass angle of 90°, an angle at which we observe dimensional scaling above 0.7 GeV. Ours is the first observation of dimensional scaling in the photodisintegration of a nucleus heavier than the deuteron, and at remarkably low momentum and energy.

In Summer 2013, we participated in the first test beam time at PSI supporting the MUSE experiment (S. Strauch). During the beam time various detector systems, including our time-of-flight prototype, were tested and data for various backgrounds were taken. We continue to work on the development of a full GEANT4 simulation for the experiment and are very excited about the prospect to develop and construct at USC the time-of-flight scintillator wall for MUSE. Michael Tuten, a student at the SC Governor's School for Science and Mathematics, worked with us this summer on understanding the GEANT4 description of elastic electron-proton scattering cross sections.

We have had a busy year moving forward our hardware projects. Our group plays a major part in the 12-GeV JLab upgrade project with the development and construction of a new addition to the Time-of-Flight (TOF12) spectrometer for the CLAS detector in Hall B, an effort that is led by R. Gothe. In the past year we completed the production and construction of all detector elements and spent the summer of 2013 installing them into the final TOF12 sector frames at Jefferson Lab. This is a milestone achievement of our group that involved efforts over several years not only of senior personnel but also of a large number of graduate and undergraduate students. Read the story shared by Evan Phelps on his experience with the project in a separate article.

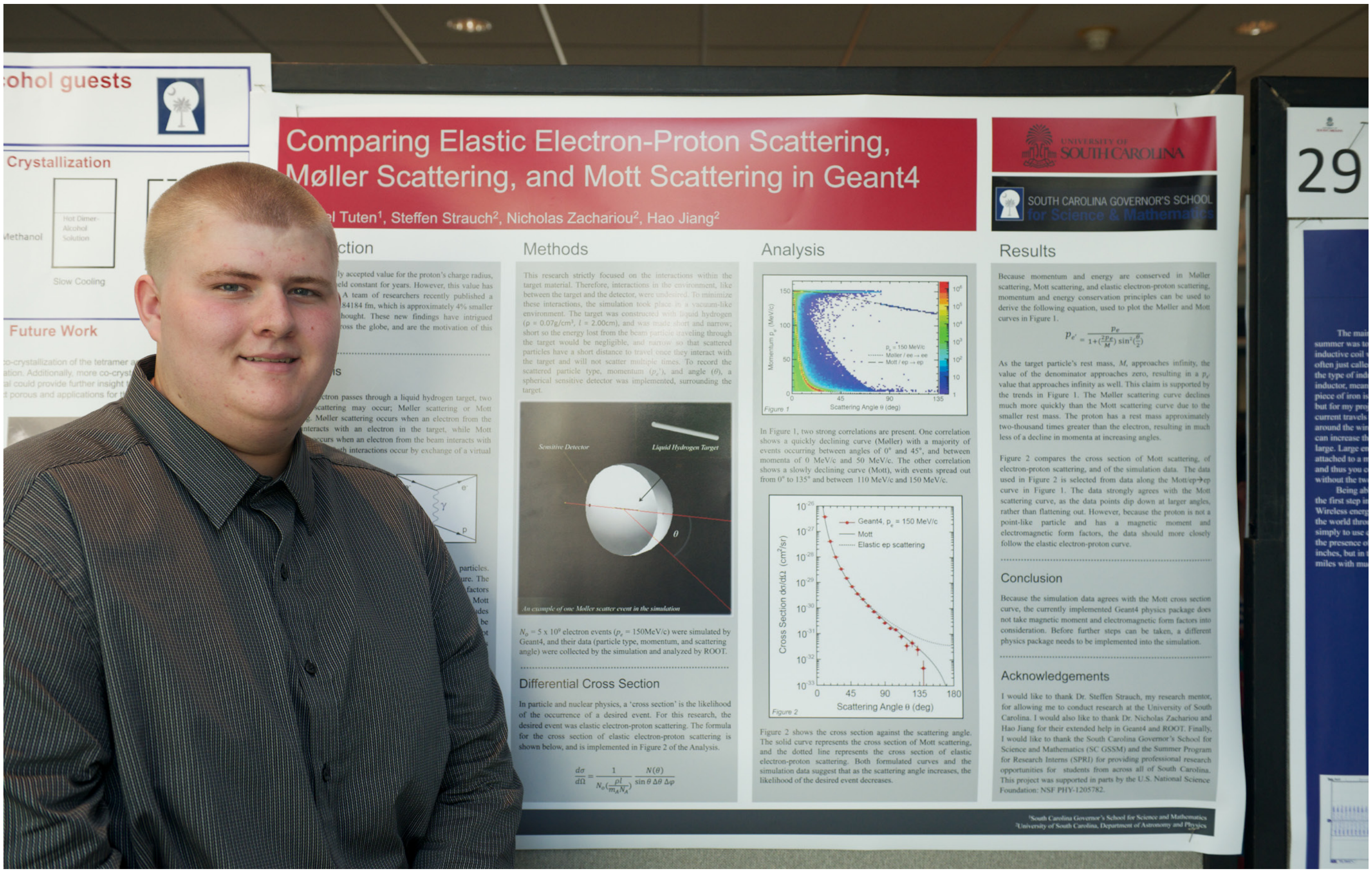
As part of the JLab R&D efforts related to building an Electron Ion Collider (EIC), we are responsible for the development of a dedicated test facility at Jefferson Lab where the performance of photon sensors in high magnetic fields can be evaluated, and we are also responsible for performing a series of tests of silicon and other sensors in magnetic fields of up to 5 T. We have secured funding for this activity through the collaborative proposal, DIRC-based PID for the EIC Central Detector (Y. Ilieva). In Summer 2013, USC undergraduate Cameron Nickle joined our effort on this project at JLab. Cameron says, "During the tests the photon sensors, Silicon Photomultipliers (SiPM) and Multi-Channel Plate Photomultipliers (MCP), will be housed in a dark box. The first step of my project was to make sure that the dark box was 'light tight' so that no light from the outside environment would enter the box during testing. A non-magnetic optical cable was made to lead from the light source to a diffuser inside the box, which allowed for controlling the light within. Then, with the help of an engineering student, I designed

USC undergraduate student C. Nickle at Jefferson Lab performing tests of SiPMs for the development of high B-field testing facility.

an apparatus that would hold the sensor in place and allow it to be rotated in relation to the direction of the magnetic field. The dark box was tested using a SiPM. Data was taken using a Charge-to-Digital Converter (QDC) and analyzed with a standalone ROOT script that I developed with some help from JLab staff. I discovered the need to install reflective surfaces to the walls of the box to allow light to be reflected onto the device when it was tested at extreme angles. I was able to show that after this modifications the SiPM was detecting photons even at angles of 90° or greater. Overall, this summer was a rewarding experience that allowed me the chance to work with accomplished physicists and engineers on a project that challenged me and helped me to develop new skills for a future career in physics." In Fall 2013, we expect to install the magnet in the lab space dedicated to the facility and to perform the first tests of SiPMs in a magnetic field. Once established, the facility will be of long-lasting value not only for nuclear physicists but also, for example, colleagues who are developing instrumentation for PET scans for small-animal or organ-specific imaging where the interest of using silicon sensors as readout elements is growing.

Last, but not least, we want to share a word about mentoring and training of junior personnel, into which we have invested quite a significant effort in the past years. We are very proud to say that we have accomplished to build a well functioning and well integrated research group with a healthy mix of postdocs, graduate, and undergraduate students, at various levels of their career development in which everyone is continuously and actively engaged by building and sharing expertise. Through regular weekly meetings and rigorous sessions throughout each year, we not only ensure that each student is progressing well in their research, but also provide training in preparation and delivery of oral and poster presentations as well as in writing competitive funding proposals. We encourage and support our students to participate in conferences appropriate for their level where they can network with other professionals in the field, promote their work, and enhance their visibility. In the past year alone, our students have presented at meetings such as the USC Graduate Student Day, USC Discovery Day, collaboration meetings, the semi-annual meetings of the Division of Nuclear Physics of the American Physical Society, and the international NSTAR 2013 workshop in Spain. Our dedication and hard work has paid off, as our students have established a strong record of winning awards and scholarships, presenting their research at national and international meetings, and being well placed at the next level of their careers.

With Jefferson Lab being in a shutdown for the 12-GeV upgrade, our commitment to publishing the 6-GeV physics results, and our involvement in several non-JLab projects, we are looking forward to another intense and productive year.



SC Governor's School student M. Tuten presenting a poster at USC about his research on electron-proton elastic scattering under the supervision of S. Strauch

High Energy Experimental/Neutrino Group

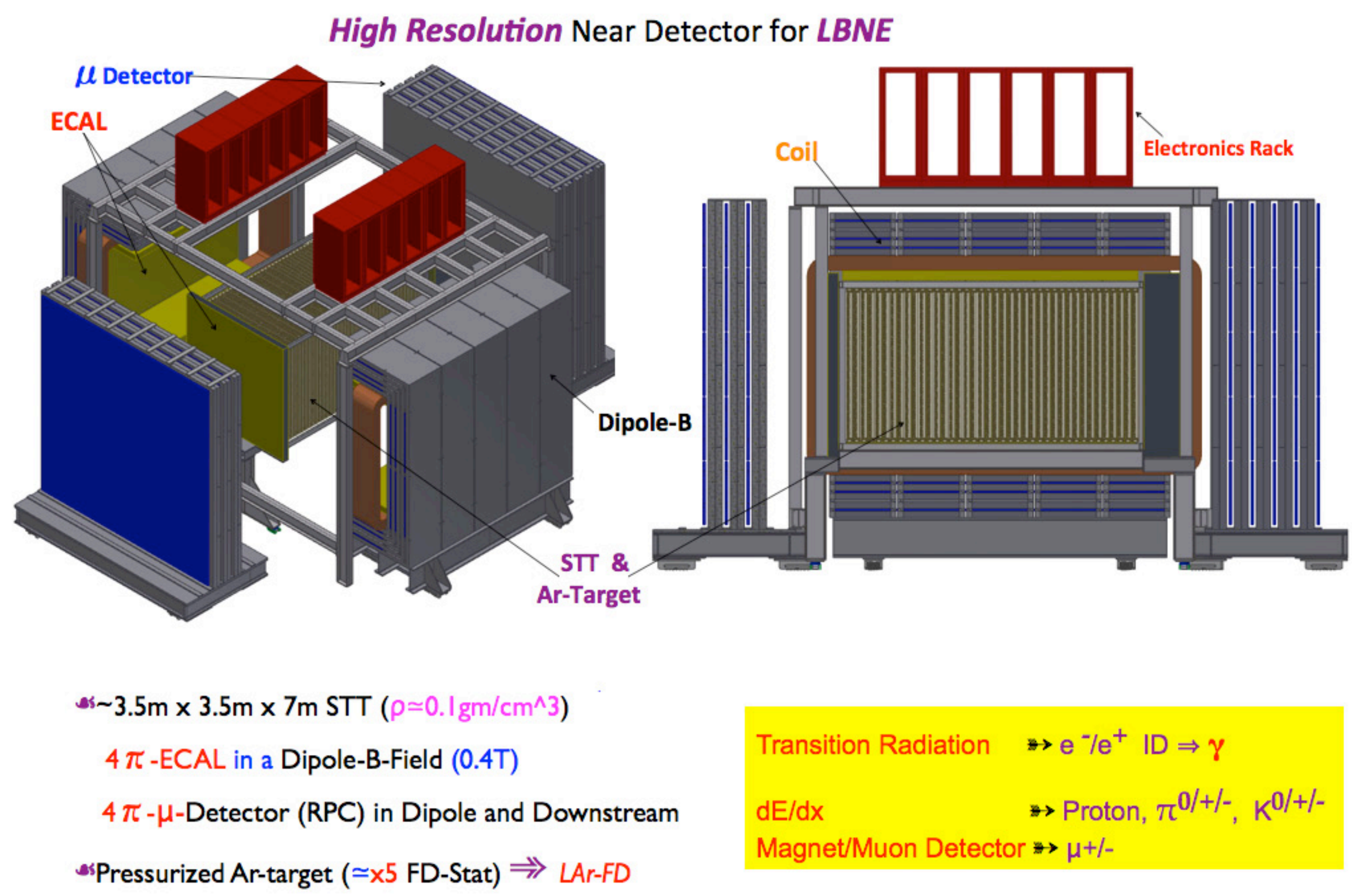


Figure 1

HIRESMNU as the reference Near-Detector for LBNE

The unique capabilities and accelerator infrastructure at Fermilab joined with a far detector 1,300 km away at the Sanford Underground Research Facility (SURF) in Lead, South Dakota, present an extraordinary opportunity to develop a world-leading program of long-baseline neutrino science. This baseline distance between near and far neutrino measurements is optimal for oscillation studies and not currently available at any existing facility. The proposed Long-Baseline Neutrino Experiment (LBNE) aims to measure three out of the four parameters that characterize three-flavor neutrino oscillations; it will be the only oscillation experiment to simultaneously measure the CP-violation phenomenon, which may help explain the matter-antimatter imbalance, and determine the relative ordering of neutrino masses. The LBNE experiment plans to take physics data starting in 2023, initially with a 708~kW beam, but later with a 2.3~MW beam introduced by Project X. The core scientific capability of LBNE will be significantly enhanced by a high-resolution near neutrino detector.

The LBNE collaboration has chosen the HIRESMNU (see Quantum Leap 2011) as the reference Near-Detector (ND). The HIRESMNU detector shown in Figure 1, comprises a high-resolution, low-density (0.1 gm/cm^3) straw-tube tracker (STT), surrounded by a fine-grained electromagnetic-calorimeter (ECAL) and embedded within a 0.4 T dipole magnetic field. Muon-detectors instrument the magnet and two stations downstream of the STT. Professors Sanjib Mishra, Roberto Petti, and Carl Rosenfeld proposed the HIRESMNU idea as a generational advance in the investigation of systematic errors affecting the neutrino oscillation and mass measurements in the precision neutrino-interactions made possible by the unprecedented neutrino fluxes foreseen in the LBNE era.

The USC group, along with Fermilab, has been working with a consortium of Indian institutions to establish their collaboration with the neutrino experiments at Fermilab, especially with LBNE. Our goal is for the Indian institutions to undertake significant responsibilities on LBNE in alignment with the ambitions of the Indian funding agencies. In 2010 and 2011, the funding agency of India (DAE/DST) set the guidelines for such a collaboration: that the physics associated with the Indian contribution be rich (capable of producing about 100 Ph.D.'s); that DAE/DST can claim "ownership" of the sub-project; and that the hardware contribution be in alignment with interest and research-expertise in India. HIRESMNU, as the LBNE Near Detector, beautifully fulfills these guidelines. It will produce over 100 measurements and searches, each surpassing the best previous result, and in the course of a ten-year operation would result in over 300 publications. The Indo-US nu-collaboration has proposed to the Indian funding agencies to design, R&D, and fabricate the HIRESMNU detector in India, which would then be shipped to Fermilab and installed in the LBNE near-detector hall. USC and Fermilab are the lead US institutions in this collaboration whose first formal meeting was held in June 2013 at Fermilab; Figure 2 shows the core Indo-US group. The Indo-US proposal, requesting about 75 million dollars for equipment and associated personnel, is a decade long commitment, and is currently under review.

Figure 2

Professors Mishra and Petti are leading the ND physics group in the LBNE collaboration. Post-doctoral fellows Drs. Xinchun Tian and Brian Mercurio, and graduate students Mr. Hongyue Duyang and Ms. Libo Jiang are participating in the LBNE related research. Scientist Mr. Chris Kullenberg and undergraduates Mr. Andrew Svenson and Ms. Kayla Hasbrouk are working with Prof. Mishra and Dr. Tian to quantitate the precision on the absolute neutrino flux at LBNE.

Liquid Argon (LAr) Research at Carolina

To compare the very high-resolution measurements conducted at the ND with those at the 1300 km away Far-Detector (FD), it is essential to understand the design and sensitivity of the FD. The LBNE project has chosen a high-resolution, multi-kiloton liquid argon (LAr) far detector, and in the summer of 2012 the USC group began to evaluate the LAr sensitivity. The LAr-work was largely conducted with undergraduate research assistants Tyler Alion, Kevin Wood, and Andrew Svenson, with graduate student Libo Jiang, and with part-time post-doctoral fellow Dr. Jae J. Kim. Tyler Alion has enthusiastically led this effort. Because the LAr is a new, and exciting, technology, the students built a toy model, pictured in Figure 3, to help communicate the physics and geometry of a LAr detector. The group conducted a NuE and anti-NuE appearance sensitivity study that yielded some surprising results, and work is ongoing to repeat the study with a vastly more detailed simulation. Tyler and Jae developed a tool to provide the physics software

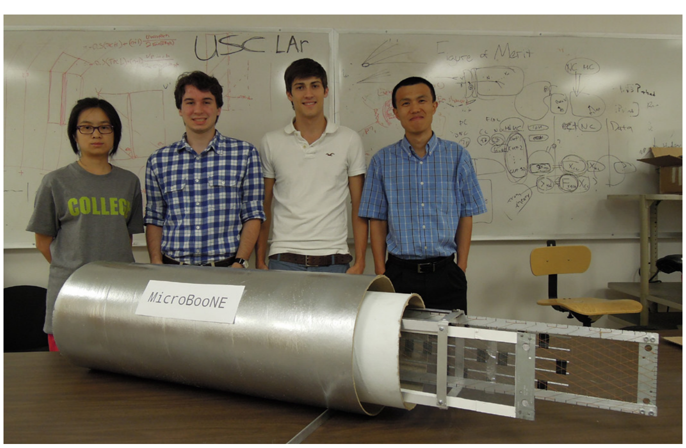


Figure 3

framework a geometric description of any proposed large-scale LAr detector, given a set of parameters, and that the detector involves a particular but common configuration of instrumentation. Figure 4 shows a rendering of one of these, the 34 kiloton FD. Tyler and Jae have also made critical progress towards eliminating a certain ambiguity in detector data, which must be done sufficiently before any other software tools can be dependable. In a year, this group has established leadership in the large-scale LAr simulation and physics reconstruction efforts.

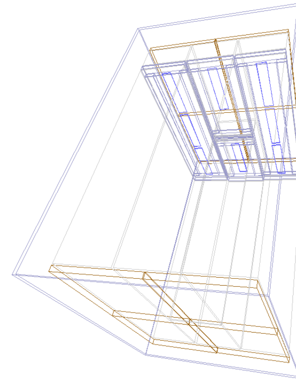


Figure 4

HIRESMNU Sensitivity Studies and Physics Results

The HIRESMNU offers a generational advance in the field of precision neutrino measurements. Tian, Mishra, and Duyang have developed four novel techniques yielding (anti)neutrino flux measurements. Indeed, it will be the first experiment to measure in situ the absolute neutrino and anti-neutrino flux at about two- to three- percent precision. One of the techniques involves the neutrino-induced coherent meson production. Measurement of neutrino production of coherent mesons uniquely elucidates the space-time structure of the weak current, provides a clear probe to test the conserved vector current (CVC), and conveys the `hadronic-content' of the weak current. Once in every few hundred interactions, a high-energy neutrino scatters coherently off the target nucleus producing a Rho meson, emitted collinearly with the incident neutrino, while the nucleus remains intact. Kinematically, the interaction is a very low four-momentum and high hadronic energy transfer process. In Neutral Current (NC) this results in a r^0 and in Charged Current (CC) in a r^+, where the two are related via the weak mixing angle. We applied the ideas developed within the HIRESMNU-LBNE research to the NOMAD data; clear signals are observed in both NC and CC. At NuFact-2013, we reported the first observation of Coherent-r^0 in NC pictured in Figure 5 where the left-panel shows the invariant r^0 mass of and the right-panel shows a 5-Sigma signal of the coherence. We also reported the measurement of Coherent-r^+ in CC —Figure 6 shows the mass and the coherence-criterion (left) and the cross-section of Coherent-r^+ as a function of energy. The precision on Coherent-r^+ is the best among all reported neutrino-induced coherent mesons to date.

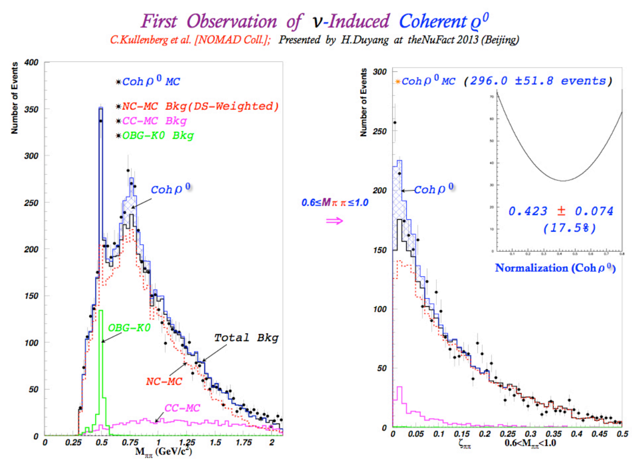


Figure 5

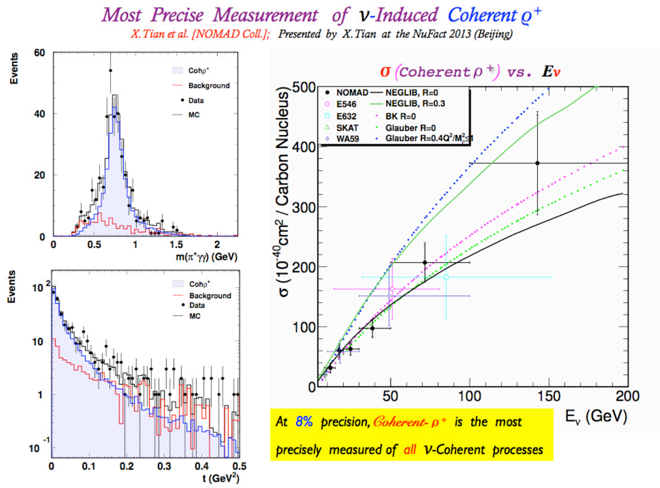


Figure 6

Prof.Petti is pursuing the precision measurement of the Weak Mixing Angle (WMA) using the HIRESMNU. A critical systematic error in determining the WMA comes from the strange-sea and the charm-quark mass parameter. Neutrino induced charm production, detected via charm's semi-muonic decay, offers the most precise quantification of the strange-sea and mass-parameter of the charm quark, m_c. Petti, with student Oleg Samoylov, conducted a dimuon analysis of the NOMAD data. We have extracted 15k charm dimuon events in neutrino-Fe interactions in the NOMAD front calorimeter corresponding to a sample of 9M single-muon events. The analysis leads to a measurement of the dimuon to single muon rate with a precision of about two percent. The key to this systematic precision is the high-resolution light target (drift chambers) data, which yield the energy scale and the pion-induced backgrounds affecting this analysis. Figure 7 summarizes the dimuon study, which is accepted for publication. Within the NLO QCD formalism, we obtain the strange-sea suppression factor of k_s= 0.591 + -0.019 (Stat+Syst), and the m_c (MS-bar scheme) = 1.159 + -0.075 (Stat+Syst) GeV/c^2.

NOvA and MINOS Experiments

The MINOS experiment continues to conduct neutrino oscillation measurements with higher precision. MINOS is the first generation of such experiments. Recently, the MINOS experiment, MINOS+, was granted approval to continue running during the NOvA operation.

NOvA, a second-generation oscillation experiment, is under construction and scheduled to begin operation in 2014. The USC group's responsibilities on NOvA include the Monte Carlo simulation, beam studies, and data-acquisition system. Mishra, Petti, Tian, Mercurio, Duyang, and Barnali Chowdhury work on NOvA.

Magellan and URA Awards

In 2012-13, Tyler Alion and Andrew Svenson were awarded the Magellan Scholarship, bringing the tally to seven undergraduate research assistants in the USC Neutrino Group. In the same year, Mishra, Rosenfeld, Mercurio, and Duyang were awarded the University Research Association Award.

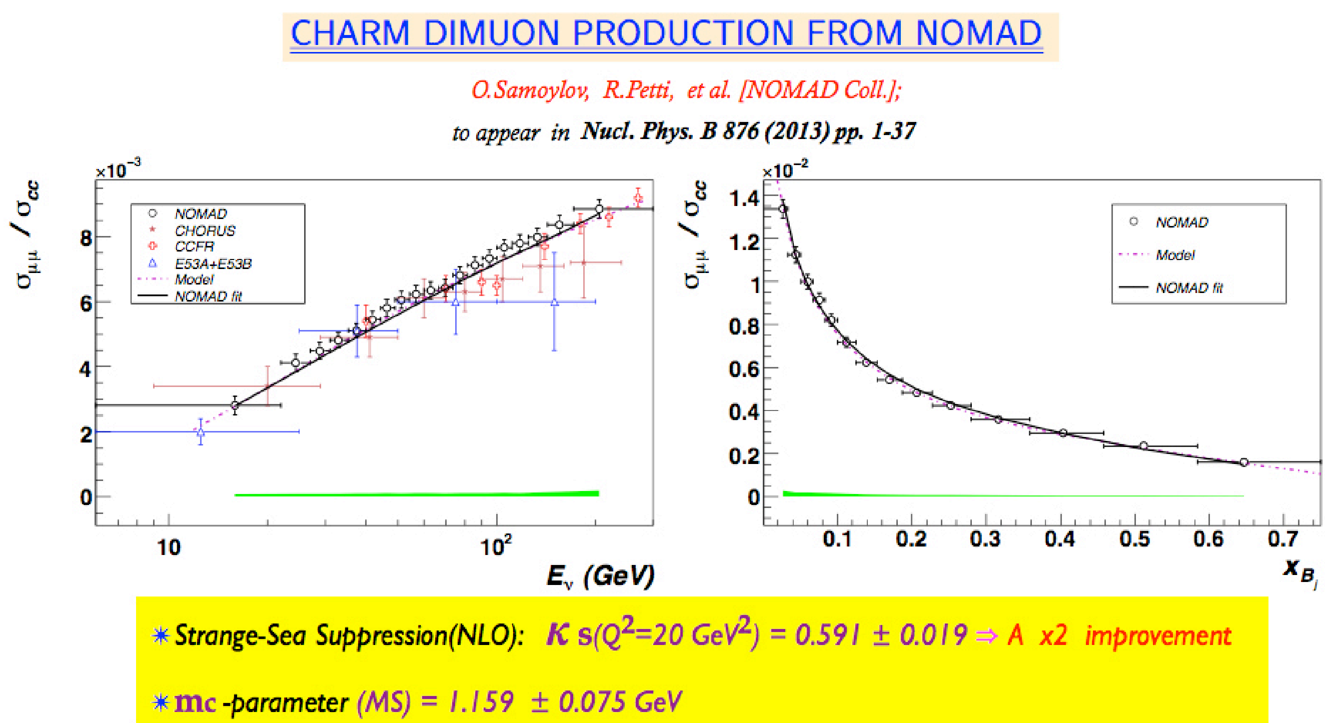


Figure 7

Particle Astrophysics Group

Faculty members: Professors Frank Avignone, Richard Creswick, Horacio Farach, Vincente Guiseppe, Carl Rosenfeld, and Jeffrey Wilson
Graduate Students: Nicholas Chott, Dawei Li, and Clint Wiseman.
Recent Ph.D. Graduates: Seth Newman (2011) and Katarina Leila Mizouni (2013).

Particle astrophysics focuses on the study of phenomena in astrophysics and cosmology associated with the properties of elementary particles such as neutrinos and Weakly Interacting Massive Particles (WIMPS), one candidate for Cold Dark Matter (CDM). In 1933, Fritz Zwicky discovered that far more mass is needed to explain the dynamics of the Coma cluster of galaxies than can be accounted for by stars, gas, and dust alone. The gravitational effects of CDM on the velocity distribution of stars in spiral galaxies are also well established. The USC group was a pioneer in particle astrophysics when, in 1985, it led the first terrestrial search for CDM in the Homestake Gold Mine in Lead, South Dakota. This experiment used a unique detector developed in collaboration with the Pacific Northwest National Laboratory (PNNL) and it was able to eliminate heavy Dirac neutrinos as the major component of CDM over a very large range of neutrino masses. The collaboration between USC and PNNL remains active today, and several Ph.D.'s from the USC Particle Astrophysics Group are on the staff at PNNL.

The Silver Jubilee of the publication of the seminal paper resulting from this experiment was celebrated at an international conference at PNNL in June 2012. Following the publication of these first results, dozens of dark matter searches have been carried out all around the world with vast improvements in detector technology. In 1994, Prof. Frank Avignone was awarded the Jesse Beams Medal of the American Physical Society for his leadership role in the first experiment. The Beams Medal is sponsored by the Southeastern Section of the APS.

The USC Group has also led several searches for elementary particles called axions emitted by the sun. Axions are predicted by the theory of Roberto Peccei and Helen Quinn that explains why the strong interaction, described by quantum chromodynamics (QCD), does not violate charge-parity (C-P) symmetry. Without the Peccei-Quinn solution, or some alternative one, the C-P-violation predicted by QCD would lead to an electric dipole moment of the neutron about ten orders of magnitude larger than the experimental bound. The USC-led axion search was based on an analysis developed at USC by an international collaboration led by Prof. Richard Creswick. It uses the coherent Bragg conversion of axions to photons in single crystals to predict a characteristic time-dependent event rate. This technique has been and is being used by other groups worldwide. It will be applied to the data from the Cryogenic Underground Observatory for Rare Events (CUORE) under construction in the Gran Sasso Laboratory in Assergi, Italy. This year, the USC group led a new search for solar axions produced by the bremsstrahlung mechanism in the core of the sun. They used the MALBEK detector, a prototype test detector, for the MAJORANA Demonstrator Experiment.

The USC group is currently concentrating on two searches for the exotic zero-neutrino nuclear double-beta decay ($0\nu2\beta$), which is only possible if neutrinos have mass and are their own antiparticles (Majorana particles). The decay mode also violates the law of lepton-number conservation. Neutrino oscillation experiments clearly demonstrate that neutrinos have mass, but they can only measure mass differences. The measurement of the rate of $0\nu2\beta$ decay would determine the absolute masses of all three neutrino-mass eigenstates.

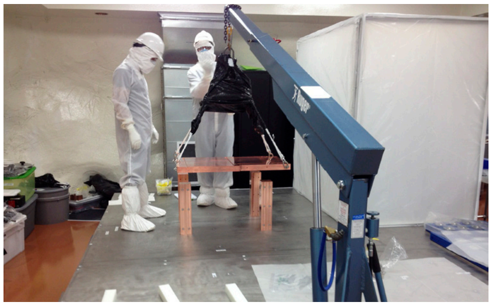
The USC group was heavily involved in the CUORICINO double-beta decay experiment in the Gran Sasso laboratory from the very beginning until it was discontinued in July 2008. CUORICINO was an array of about 42kg of TeO_2 cryogenic detectors operating at ~0.008-K, and it set a lower limit on the half-life for the $0\nu2\beta$ decay of ^{130}Te. Currently the particle astrophysics group is involved in the construction of CUORE, a 760-kg detector using the same low-temperature technique. The group's main responsibility is the production of the electronic system led by Carl Rosenfeld and the construction and operation of the first tower of CUORE (CUORE-Zero), which began operation in the spring of 2013. The USC group maintains research associates and graduate students at the Gran Sasso Laboratory year-round.

The USC group is also playing a leading role in the MAJORANA Demonstrator Experiment, a 21-million dollar research and development project designed to establish the feasibility of building and operating a ton-scale ^{76}Ge double-beta decay experiment. The principal technology being used in MAJORANA is a vastly improved version of the IGEX experiment, also led by the USC group in the 1990s. Funding for the ton-scale experiment will depend on the level of success of the Demonstrator project. All the USC activities are supported by major grants from the National Science Foundation.

Last year, Prof. Jeffrey Wilson joined the USC Particle Astrophysics Group. He brings computational expertise including Monte Carlo simulations using GEANT codes as well as the most up-to-date data analysis techniques. He most recently worked on data analysis for the BaBar Experiment at the Stanford Linear Accelerator Collider (SLAC) facility. This year, we are also fortunate to have recruited Prof. Vincente Guiseppe, formerly of the University of South Dakota. Guiseppe is a task leader in the MAJORANA Demonstrator Experiment in charge of the construction of the complex shield.

Presently, and for the past few years, the USC Group has been deeply involved in the major construction issues for CUORE-0, CUORE and MAJORANA. Upon their commissioning, the role of the group will transition to mainly running shifts and analyzing data. In addition, the group is introducing a new concept of using the inner detectors of the CUORE array to study the decay of ^{130}Te to the first excited 0+ state of ^{130}Xe. The decay to the excited 0+ state is followed by a gamma-ray cascade to the ground state; by tracking these gamma rays it is possible to eliminate a large part of the background. Jeff Wilson is leading the team in carrying out the complex simulations needed to compute the efficiencies of the many possible gamma-ray interaction scenarios and the design of the associated data analysis codes.

This field continues to produce exciting research opportunities and has attracted excellent funding support for faculty and student participation.

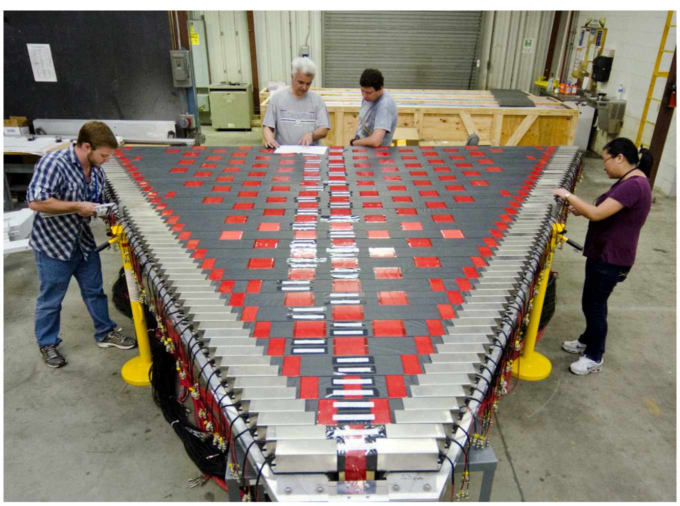


Student Clint Wiseman (left) and Assistant Professor Vincente Guiseppe (right) directing the initial construction of copper shield for the Majorana Demonstrator neutrinoless double-beta decay experiment. The cleanroom laboratory is located 4950 feet beneath the Black Hills of Western South Dakota. Guiseppe manages the design and construction of the experiment's ultra-low background shield.

Probing Matter at the Precision Frontier of Physics

by Evan Phelps, Graduate Student

The Experimental Nuclear Physics (ENP) group at USC achieved world-record time resolution with their Time-of-Flight particle detector (TOF12) designed and constructed for Thomas Jefferson National Accelerator Facility's (TJNAF's or JLab's) large acceptance spectrometer, CLAS. In July of 2013, after almost ten years of work that included design, prototyping, construction, testing, and assembly, we shipped TOF12 to JLab for final integration and commissioning—on schedule, within budget, and surpassing design requirements. Serving as CLAS's primary device for particle identification, TOF12 will play a vital role in an international physics program that aims to answer basic questions about the universe: What is the universe made of? What holds everyday matter together? How is the mass of visible matter generated from almost nothing? Toward this end, USC's ENP group contributes significant data analyses and leads strategic coordination initiatives, establishing itself as one of the leaders in the international program. The group's full lifecycle ownership of the TOF12 project extended their program into the field of detector physics and provided even more opportunities for USC students and researchers to contribute to world-leading efforts focused on revealing the physics beyond, and hidden aspects of, the Standard Model. As a student, I was drawn to these rare opportunities to explore the basic questions while also developing expertise that spans many layers of experimental physics, from detector materials and hardware to data analysis and interpretation.



Contingent from the University of South Carolina working at JLab on assembly of one of the six detector arrays of TOF12. Graduate student James Thomason (front left) and Ye Tian (front right) perform alignment of the counters on their mounting frame under the direction of Prof. Ralf Gothe (back left) and post doctoral researcher Gleb Fedotov (back right).

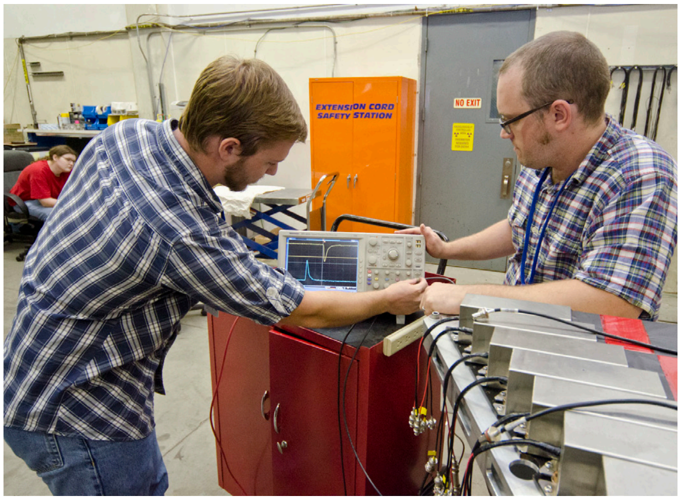
From its original operation in 1997 until its final 6-GeV experiments in 2011, the CLAS detector of the 6-GeV Continuous Electron Beam Accelerator Facility (CEBAF, and the "C" of CLAS) offered unique opportunities to investigate the transition between particle and nuclear physics. Based on the success of the 6-GeV program, the Department of Energy's Office of Science prioritized the 12-GeV upgrade of CEBAF as its number one recommendation to deepen, with unprecedented precision, our view of the transition into its most rapidly evolving region. This precision frontier of physics might sound like a technical niche where our fundamental understanding is only refined; on the contrary, it is the key to understanding the dynamics of the strong interaction, which are responsible for the emergence of ground and excited nucleon states. The description of how the strong interaction, described by Quantum Chromodynamics (QCD), dynamically generates the nucleons and, with them, 98% of the mass of ordinary matter, could be the most significant and challenging part of the Standard Model yet to be explored. Filling this knowledge gap is the primary motivation of the 12-GeV Upgrade at JLab, which drove the requirements of the TOF12 detector.

The physics value and technical details of the CLAS detector are well documented, but the pedagogical merit of the TOF12 project at USC, from the perspective of a student, is rarely discussed. Offering both broad and deep research experience, the TOF12 project employed the efforts of more than twenty undergraduate and graduate students over six years. Student experiences ranged from semester-long sub-studies to full-lifecycle engagement. TOF12-related research fulfilled several Masters theses and, as in my case, complemented Ph.D. research with a component of detector physics and involvement in project management.

In 2006, before, and in anticipation of, entering the graduate program, I started working on the TOF12 project under Professor Ralf Gothe, the primary investigator and manager of the project. Preliminary investigations had been performed by Dr. Gothe and graduate students under his guidance, but otherwise the opportunity was "ground-floor": the lab was not built; the custom tools were not designed; the candidate components of the detector were not evaluated; and the measurement methods were not developed. I brought some non-academic skills from several years of professional software development, but I had no experience with lab setup, particle detection, or nuclear instrumentation. Starting with detailed studies and quantitative evaluations of the electronic building blocks of systems that translate detector signals into time and energy information, I slowly built a framework to put together and tune full systems of electronics and data acquisition. These systems allowed for the subsequent development of time resolution measurement methods and, in turn, testing of any combination of components, from detector materials to cable connector types. From the optimal configuration, we constructed prototypes to serve as benchmarks during the manual construction of the 384 "mini-detectors" that comprise the TOF12 detector.

During this bottom-up process, students were entrusted with the vast majority of tasks in a way that allowed for progression from labor-oriented, directly supervised work to goal-oriented, complex assignments with great latitude in method. Much like my experience in private industry, efforts and ideas were kept on track with weekly reviews of progress, allowing for continuous feedback and improvement. This level of hands-on cultivation of student knowledge and skills within a "real-world" project proved to be unique within the larger 12-GeV Upgrade Project, which is most notably demonstrated by the official project, Technical Review, at JLab. Not only is the USC ENP group the only contributor whose technical presenters were graduate students, but our team also received top marks and statements of confidence from world-leading physicists appointed to evaluate the project. Moreover, the exposure gained by students led to excellent ties with physicists beyond USC, and the research experience played an important part in securing fellowships and other external funding for some students.

TOF12's construction phase is complete, but the opportunities and value generated by the project are ongoing for both USC and individual students. As JLab's 12-GeV era begins, the ENP group is poised to provide ongoing detector expertise and service to the CLAS collaboration as they work to complete our knowledge of the mostly unknown transition between particle and nuclear physics. The TOF12 development infrastructure serves as a longterm asset for prototyping and building new detectors for other facilities and for the laboratory portion of undergraduate and graduate physics courses. For individual students—even those not pursuing research careers—the hands-on hardware and software work adds unusual breadth to their experience and demonstrates to potential employers their ability to transform research-informed knowledge into practical applications.



University of South Carolina student James Thomason (left) and Robert Hedrick (right) perform signal check of one of the TOF12's 768 photomultiplier tubes in the assembly area at JLab.

2013 R.L Childers Midway Physics Day at the S.C. State Fair

We had another fantastic year with the R.L. Childers Midway Physics Day at the S.C. State Fair as over 3,000 students from nearly 70 high schools around the state came out to participate in the annual event! Along with our staff and faculty, many of our graduate and undergraduate students volunteered their time to show off a variety of hands-on physics demonstrations. This event was created by Professor Richard Childers to provide a fun lesson in physics for high school students from around the state. Many of the teachers make lesson plans around the day's events and are able to take the information gathered here back into the classroom to be applied towards their students' coursework. By providing real-life physics experiences, we hope to encourage more students to pursue studying physics when they graduate from high school.

Check out our links below for a video clip and pictures from the day's events!
WLTX TV News Clip: http://www.wltx.com/video/2746283777001/1/Physics-Day-at-the-State-Fair-
Photos on our Facebook page: https://www.facebook.com/USCDepartmentofPhysicsandAstronomy

Another Honor for the Physics Faculty

Professor Horacio Farach had a distinguished career in our department from 1968 until his retirement in 2003. He moved back to his native Argentina but makes frequent trips to Columbia and USC, where he remains a member of the Particle Astrophysics Group and continues to write books with Distinguished Professor Emeritus, Charles Poole.

This year, Prof. Farach was given a very high honor by the government of Argentina. Each year, the Commission of Culture of Argentina recommends fifteen to twenty Argentine citizens to the House of Representatives of Argentina to be recognized as "Mayores Notables Argentinos," in English, "most remarkable Argentine citizens." The candidates are all 75 years of age or older, must have earned distinguished international reputations, and must be recognized as having had lives that serve as beacons of light that will guide Argentine men and women of tomorrow. The translation of the last sentence in the statement of criteria reads: "They are our past, our present and the seed of our future."

On Friday, August 23rd, 2013, this honor was bestowed upon Prof. Farach in the Cámara de Deputados de la Nación, the equivalent of the U.S. House of Representatives. We offer our most sincere congratulations to him and thank him for bringing honor to our department and college. Associate Dean Robert Thunell and Professor Richard Creswick traveled to Argentina as official USC representatives. While serving on our faculty, Prof. Farach was awarded a number of honors including: the Russell Research Award, the Mungo Teaching Award, the Jesse Beams Medal of the American Physical Society (sponsored by the South Eastern Section), and the Luis Leloir Medal of Argentina. Additionally, Prof. Farach was awarded the honorary degree Doctor Honoris Causa from the Universidad Nacional de San Martin in Buenos Aires, Argentina in 2012. Though retired for ten years, Horacio Farach continues to bring honor to our department and the university.

Quantum Leap

Department of Physics and Astronomy
University of South Carolina
712 Main Street
Columbia, SC 29208

Telephone: 803-777-8105
Fax: 803-777-3065
Email: wonge@sc.edu
www.physics.sc.edu

Chair:
Milind Purohit

Director of Graduate Studies:
Richard Creswick

Director of Undergraduate Studies:
Jeffrey Wilson

Editors:
Frank Avignone
Evelyn Wong

Layout & Design:
Mark Harmon

Space Elements imaged by Alex Mowery from the Melton Observatory