Dear Alumni and Friends:

Greetings from Charlottesville! I hope this Newsletter finds you all healthy and well! It is my great pleasure to write this quick update. This Fall brought a more normal way of life in the department, but as we all know quite well, Covid hasn’t left us. We managed to get through the start of the semester despite many falling ill to the virus. Our faculty have helped each other get through the day-to-day teaching as we look forward to a year that almost looks like pre-pandemic times. Similarly, we watched students adapt to the new circumstances, and are proud of what they’ve accomplished. It is hard to imagine how different life was in the pre-Zoom era — I often hear from colleagues here and elsewhere how much they value in-person teaching. This is true in the sciences. With many conferences canceled or going on-line, the young generation of physicists has lost the truly invaluable ability to meet and exchange ideas with fellow physicists and explore job prospects. The return to in-person meetings is slowly catching on, and I’m happy to announce that with a new alumnus donation, the department will be able to provide financial support for students to travel to conferences and workshops starting next year.

This Fall has also brought many changes and new norms in the Physics building. With the renovation of the ’80s addition well underway, all except the introductory laboratory courses meet outside the Jesse Beams Laboratory, and some of us are learning to navigate to new buildings across grounds. Phase 1 renovation is expected to be completed around Christmas time. Its completion will render a new second floor in the ’80s building with an active learning classroom along with many newly renovated lab spaces for research as well as offices. We look forward to bringing new research activities in our department.

Preparations are currently under way for the next phase of the renovation, Phase 2. This phase will impact half of the building on all floors. The department has been busy with relocating labs and offices and getting ready for the next phase to begin. Big construction equipment and noise is an everyday norm now, and there is less student traffic than we were used to from past years. Nonetheless, it is a joy to see physics students on the third floor, making full use of the former library space that has recently been converted to student study areas. As I pass by every day, I see them gathered in those rooms, working together and sometimes even playing musical instruments, chatting and laughing. It is a reminder of the sense of community that our students share with their fellow classmates. Students will be relocated for a second time until student space is available after Phase 3.

May ’22 graduation was quite the event. Held jointly with the Astronomy department, this was the first in-person graduation after returning to in-per-
son teaching, and both faculty and students felt excited and relieved that we were able to continue one of our beloved traditions. The graduation ceremony was held in Alumni Hall and brought families and friends of our graduates out for the celebration. Just as in the past, graduation brought recognition to many of our students for their accomplishments. We congratulated Gracemarie Buehmann, Michael Stepniczka and David Winters for winning the outstanding undergraduate major award, David Garwood and Michael Stepniczka for winning the Stephen Thornton award in Physics for undergraduate research, and William Musk for winning the Physics Community Leadership award. This year we also congratulated five recipients of the Deaver Scholarship award. These are Alex Emmert, Dawn Ford, Charlotte Hoelzl, Bejoy Sen and Kai Vylet.

Graduate student Miller Eaton won the 2022 1st place prize for outstanding graduate research in Physics for excellent PhD thesis work. This year the department awarded two 2nd place prizes, one to Xiao Hu and another to Andrew Sutton. Physics major John Leonardi was elected to the Phi Beta Kappa society.

The Physics department also resumed its famous National Physics Day Show. Performances were primarily carried out by undergraduate students in collaboration with the Outreach committee, and the room was filled with kids of all ages from Charlottesville/Albemarle. The event drew many people from the area and it was a huge success. The event was also a bittersweet goodbye to lecture hall 203. The auditorium is now closed for the renovation and when completed by Phase 3, it will be a very different place. This year we are celebrating the retirement of professors Brad Cox and Lou Bloomfield. In case you are wondering what will happen to Lou’s List, we hope that it stays on and continues to inform users of the course offerings in a much more concise and convenient way than SIS. Professors PQ Hung and Donal Day will be retiring by May of ’23. Lastly, we welcome Professor Jency Sundararajan on the faculty. Jency joined us last summer and is teaching the pre-medical physics courses.

I wish you all a great year ahead, and good luck with all your endeavors! To those who graduated, remember to stop by when you visit grounds.

With my best regards,
Despina Louca
Chair, Department of Physics

**Recent Graduate: Stay Curious and Follow Your Heart**

Ilya Andreev, Class of 2019, BS Physics and BA Mathematics

Hi! My name is Ilya. It’s now been some time since I graduated with a Bachelor of Science in physics and a BA in mathematics from UVa in 2019. The world surely was different back then. After I graduated, my heart led me in a completely different direction: I decided that understanding the complex inner life of living cells was my true calling (or perhaps the grass is just greener on the other side). Now, I am pursuing a PhD in Biology at MIT, where I study the supportive functions of macrophages — commonly known as the hungry immune cells that like to eat bacteria and other debris (“macro” — big, “phage” — eat) to keep the organism clean and healthy. However, eating is not all they do. Some macrophages reside quietly in tissues and act as “sensors”, observing what’s happening in the rest of the organism, for example, by surveying blood content and communicating this information to the rest of the tissue. Cells talk to each other all the time by sending and receiving signals in the form of proteins and small chemical molecules. I am curious about how exactly these signals are relayed at the molecular level by tissue-resident macrophages, what other cells in tissue they communicate with, and basically everything these macrophages do that doesn’t directly involve eating other stuff.

You may wonder how a math and physics double major ended up in the field of life sciences. The road there was quite chaotic, to put it lightly. My first research experience was with Prof. Marija Vucelja, with whom I worked on studying a peculiar similarity between the mathematics of spin glasses and the dynamics of sexual populations. The equations looked so similar that phenomena discovered in one model could be almost seamlessly trans-
ferred to the other, and statistical physics was the link between them. Afterwards, I joined forces with Prof. Xiaochao Zheng to investigate the different models of dark matter dynamics in galaxies. As the LHC pushes the limits of possible particles beyond the standard model that could constitute the dark matter, and astrophysicists reject more and more non-classical models, the question of whether dark matter is made of unseen particles or represents a physics-defying astronomical phenomenon remains open, and it is the question which I’m most excited to see the next big breakthrough news on. My biology journey started with being on the iGEM Synthetic Biology Team at UVA, where our team focused on improving wastewater treatment systems by designing a bacterium that can combine two energy-consuming water processing steps into one. This hooked me further and led me to join the lab of Prof. Keith Kozminski, where I studied the effect of mutations of oxysterol binding protein homolog (Osh) proteins. Here, for the first time ever, I got to play with live bacteria and yeast and realized that I’m having so much fun and there’s no way back for me. Two more amazing years at NIH in the lab of Dr. Meru Sadhu studying killer viruses and killer toxins in yeast convinced me that a science PhD is the way to go, which is how I ended up in Prof. Hernandez Moura Silva’s lab at MIT. As you can see, I followed my heart, worked on a wide variety of projects, got a taste of what research is like in different fields, and ultimately ended up in a field and a place where I feel like I completely belong.

Over the last energetic year in Cambridge, Massachusetts, I spent a non-trivial amount of time walking down the Infinite Corridor and in the hallways of the nameless double-digit buildings on the MIT campus, wondering why I am here, what I am doing with my life, and being nostalgic over how much the intellectually stimulating atmosphere here reminds me of UVA Physics. While UVA Physics has many qualities, I think of it primarily as an army training: you are thrown in the ocean of really tough problem sets, carrying parts of a broken life boat of knowledge, while all the students around you seem to have the other parts that you need to build your own. The only way to survive is to swim forward like mad, make new friends, play off each other’s strengths and be open to receive and share the pieces of the life boat. In the end, problem sets come and go, but the many lifelong friends you make — brothers and sisters in arms, bonded by fire — stay with you far beyond college, and often for a lifetime. Nobody will remember the bad movies we watched at Physics Bad Movie Nights, but everyone remembers how awesome it was to stay till 2 a.m. along with your best friends.

Throughout my time at UVA, I kept the habit of challenging myself by taking courses that were beyond my preparation. (Yep, I know that’s you, you eager beaver.) I often found myself banging my head against problems that, even if you solved them, you’re still not sure what you’ve learned from it. I’m sure that’s how Quantum Physics must’ve felt to you. There will be times when you can do the math easily, but the physics behind it will elude you completely (which in my view is most annoying and can easily make you doubt your ability to become a good physicist). Other times, you can see right through a physical phenomenon, but the calculations behind it are so complicated that you’ll immediately want to cry yourself to sleep into a pillow. Eventually you’ll get it right, but there will be a lingering question: “I solved it, but what have I really learned?” It is a natural feeling, since we, curious physicists, always seek a complete, and not partial, understanding, and it is this feeling that brings us true joy and fuels our desire to learn more. We all go through this phase. Stay curious. Embrace that, most of the time, you won’t know what you’re learning and appreciate the smallest bits of the puzzle you piece together, even if the whole puzzle isn’t remotely clear to you. This is true regardless of whether you’re a freshly minted first-year, or an upper year PhD student. Learning any science is no different from learning a language — you start by learning simple words (internalizing concepts and memorizing basic laws), then building sentences (solving problems), and eventually, after years and years of stringing different random sentences together, you become an expert user of the language without even realizing you can speak it. Amazing!

Some of your friends may seem to inevitably learn faster than you, which can be discouraging and lead you to think you’re not smart enough. As a first generation/low income immigrant from a simple provincial town in Russia, I felt this very strongly. But what I never factored into my equation was the difference in our levels of preparation. In reality, the luckiest of us have had the brightest and most caring mentors guide their path to science starting from middle school. I did not (although my teachers were hands-down the most caring teachers in the universe). So, even if you and your peers start college on the same day, remember that nobody truly starts at the same level. Aside from Evariste Galois, there are no geniuses in this world — they are only a myth. There are only more prepared or less prepared students, a factor which is completely at the mercy of the circumstances and the environment.

Just work hard, be curious, and remember — you’ve got this!
Physics Renovation Update

Peter Arnold

We are now well into the first year of the multi-year Physics building renovation project, and we are all learning (or not) to live with unpredictable, loud bouts of hammering and industry. The renovation is a “phased renovation in place,” which means that the building is renovated one section at a time, and we have to move labs and offices and generally compress the department as the renovation moves through the phases. We are now in Phase 1, which covers the green portion of the accompanying diagram. (But you may ignore for now the green lines running along the roof ridge of the main building.) The first floor and basement of the Phase 1 section were originally constructed in the 1980s and are known as the “1980s addition” or “old addition.” The lab and office space there is all being renovated now, and the accompanying picture of the interior gives you an idea of how it has been stripped down. Also, a brand new level is being built atop the 1980s addition, as shown in the recent picture of the construction as seen from the Physics parking lot. The most prominent use of that new floor will be for a large, Active Learning classroom for university class meetings designed to facilitate student interaction and collaboration. There will also be three new offices on that floor, and a hallway connecting the second floor of the main building to the top floor of the 1990s addition. The 1990s addition (also known until now as the “new addition”) corresponds to the uncolored portion of the building diagram, which is not being renovated.

Construction schedules are always subject to delay, but, at this writing, the plan is that Phase 1 will end and Phase 2 begin near the very end of 2022. Phase 2 construction covers the yellow area in the diagram, which is roughly 60% of the main building. That will require the greatest compression of the department during the renovation (exhale ... hold it ... hold it!), and that phase is planned to last 1 to 1½ years.

There’s also the attic, which (despite the yellow color coding) involves work stretching over all three phases. Older readers may remember or may have heard that the attic burned up in 1994. The university did not have the resources at that time to bring the space up to code for resuming day-to-day occupation, and the attic has been used only for storage ever since. The stored items were cleaned out at the end of last year, and, when completed, the renovated attic will be home to new offices and a small conference room. To give those attic offices natural light, long skylights will be created running along the peak of the roof, and glass walls will be used to get that light into the offices. It will be a nice transformation of what’s been a drab and dusty space!

Phase 3— the last phase of the renovation—will cover the rest of the main building (and the completion of the attic). But that’s so far away, you’ll have to wait for a future Physics department newsletter to hear about it.
The Annual Physics Day Show is Back!
Darren Upton & Ishika Gobin

Three, two, one: Boom! The explosion of the methane-filled balloon started the 26th Annual National Physics Day Show with a bang. On April 21st, 2022, after a two-year pause due to the Covid-19 pandemic, the Physics Building was once again filled with visitors. Local school children and their parents sat at the edge of their seats as the room resounded with their excitement. Since this was the last time before the renovation that this auditorium, the famous room 203, would host the Physics Day Show, we followed the suggestion of Lecture Demonstrator Dr. William (Al) Tobias that we should make a bang.

UVa’s National Physics Day Show has served a vital role in connecting the physics department to the Charlottesville community by introducing families to intriguing physics concepts through fun and flashy demos. This year’s show featured the physics of communications, with exciting and intriguing demonstrations presented by the University’s students. With the expertise and guidance of Dr. Tobias, the true star of the show, we presented three series of physics demos and experiments to showcase three methods of communication: classical, electricity and magnetism (E&M), and potential future communication methods.

The classical group, led by Prof. Xiaochao Zheng, used visible light and sound to keep the audience alert. They used focused light and parabolic mirrors to light a match and let children hold long, hollow tubes above a Bunsen burner to showcase resonance. They even blasted a bottle rocket through the audience for science.

Next, the E&M group dazzled the audience with demonstrations involving electricity and electromagnetic radiation. Headed by Professors Peter Schauss and Tom Gallagher, the team showed various E&M characteristics used for communication over the past 200 years. Their demos ranged from simple visuals with fiber optics to an electrifying scene with a Tesla coil and Faraday cage to using a modified flashlight to transmit a signal to play music. To describe future modes of messaging, the final group introduced the audience to general relativity and spacetime to discuss gravitational waves. Professor Kento Yagi’s astro team used a trampoline-like surface and dense balls to help visualize the spacetime distortions caused by massive celestial objects. Dr. Alex Saffer showcased a gravitational wave analog using a drill and a water-filled fish tank. He then discussed the feasibility of using the weak, difficult-to-detect ripples in spacetime to communicate over vast distances. Dr. Saffer’s experience and passion for outreach showed as he closed the evening with a style reminiscent of some of the great science communicators. The evening was a success, and after showing their appreciation with a great round of applause, the audience left eager to attend next year.

Show participants:
Dr. William Al Tobias, organizer and supervisor of all demos
Prof. Marija Vucelja, host of the 26th Physics Day Show
Prof. Xiaochao Zheng’s team on classical ways of communication: Darren Wesley Upton, Michael Chenen Choi, Maija Helena Hatanpaa
Prof. Peter Schauss and Prof. Tom Gallagher’s E&M team: Lara Shaan Ojha, Quentin Hawkins Simmons, and Troy Story Meink
Prof. Kento Yagi and Dr. Alex Saffer’s astro team: Leslie Kim, Ishika Gobin, Gabby Elena Nicolescu, Riley Niamh May, and Sarah Elizabeth Shriner.
Active Learning Reform for Introductory Physics Courses

My Journey to Active Learning
Xiaochao Zheng

When I first started teaching Introductory Physics 1 in 2012, I was surprised by how much material we needed to cover in a short semester. In the Chinese education system where I grew up, we start Physics in the 2nd year of middle school and Chemistry in the 3rd year, with both continuing into 3 years of high school. By the time we take the standard college entrance exam, we would have had 5 years of Physics and 4 years of Chemistry. Still, I vividly recall finding the problem of a cylinder rolling downhill ultimately confusing, and I always felt that I had to rely partly on luck to get it right. Now, we are supposed to teach how to solve this in 7 weeks of class time in Physics 1 where a significant portion of the class have never even taken physics before.

Without much experience teaching large classes, I followed the least-effort path: I would present slides in the large lecture hall, do demos, assign MasteringPhysics homework, and give three exams that contain only multiple-choice problems. In fact, this is how our non-major introductory physics courses have been taught for the past 1-2 decades. With the exception of a couple of award-winning instructors, student evaluations for these courses have been painful to read. Our courses are known to be “insanely hard” across the college and engineering school. Looking back, some students acutely pointed out that “basically the lecture needs to be completely changed, cause it wasn’t working”. Indeed, many other universities have adopted the “studio” or “active learning” (AL) method in their introductory courses. However, such new teaching methods often require very low student-to-instructor ratio and dedicated teaching space, sometimes in the form of a glorious new STEM building that we do not have.

I was not able to find a low-cost solution to improve the teaching effectiveness of our large classes for many years, that is, until I tried out group quizzes in the Modern Physics course that had a class size of up to 80. To ensure attendance to the dedicated discussion sessions, I designed weekly quizzes that students would solve in groups. It was through observing these quiz sessions that I realized the power of group learning: As soon as everyone starts to feel comfortable, questions pop up nonstop, students talk to and help each other, and the classroom suddenly becomes alive and filled with excitement! It appears that I have found a way for students to reveal what they have (or have not) learned such that we (instructors and TAs) can offer help effectively. Most important, students help each other sooner than we can. Because of the collaborative learning nature, I could make these weekly “quizzes” quite involved, challenging even the most experienced students, while raising the learning standard for the whole class.

In Fall of 2020, I took the plunge and adopted these methods in PHYS1425 which was completely online that semester. I had to use Zoom breakout rooms to administer the weekly quiz, and many students reflected it was the only interaction they had with the outside world. Luckily, we went back in person in Fall 2021, and I was able to explore AL method in its real form and fine tune even more, from adding collaborative exam preparation sessions, to seemingly trivial tips such as utilizing white boards in the classroom. In addition to AL quizzes, another major difference from my prior teaching method is that I require chapter summary assignments to promote reading and metacognition, and all homework and exams consist of written problems. Student satisfaction improved drastically, and I can now dive deeper into more sophisticated topics such as using data to study the true inclusiveness of my teaching.

As this newsletter is written, we are moving all introductory physics courses to AL format. The importance of empowerment through social interaction is often overlooked in our field because, technically, physical laws do not need any social skill to understand. While

See Active Learning on page 7.
this is somewhat true, collaborative learning provides the support that students with less physics experience deeply need, while giving those with more experience purpose and value because they can make a difference in helping and teaching others. Many of them continue along the journey and become undergraduate TAs for the following semester. In this issue, you can see several students’ contributions that provide different perspectives on the AL method. Meanwhile, I would like to provide a word of caution that while AL is a fantastic teaching modality, an AL session can be a waste of the precious lecture time if the collaborative learning assignment is not well defined, too easy, or too difficult and without scaffolding, or too detached. If we believe the most important aspect we have learned in physics ourselves is problem-solving skills (perhaps next to the beauty of physical laws and the tranquility they offer), then developing assignments that are sufficiently and appropriately challenging should be the most important part of the course design.

I used to think that I could not teach the real essence of physics within a short semester. This is no longer the case. Sometimes, I even dream that I can inspire an appreciation for the beauty of physics in my course. I hope such appreciation, which drives me to move forward day after day in research, can inspire my students to move forward with tenacity in their choice of profession as well, for such desire for learning and excellence is what we can motivate and inspire the best as faculty of an R1 university.

Physics is Rarely a Solitary Subject
Becca Danese
Class of 2023, Environmental Science & German major
(Spring 2022 PHYS1425 student)

I went into Physics 1425 expecting to hate it. I took AP Physics 1 in high school and didn’t dread it, but found it frustrating and needlessly complex. Shouldn’t physics, a subject that aims to explain the very rules of the universe, a foundational human curiosity, be explained simply and in a way that does not frustrate students to tears? I did not score high enough on the AP exam and so when I got to UVa, I had to take Physics 1425 and 1429 to meet the physics requirement for the Environmental Science BS degree.

I was surprised by what the class turned out to be. I had no idea it was an active learning section when I joined, but I could not be more pleased by what I ended up with. We were put in groups and given difficult problems to solve, but we had all class to do it and each other to bounce ideas off of. I learned a great deal during these “quizzes”. They forced us to put together what we had learned and try multiple techniques before we could arrive at the answer. It was hard, but satisfying.

Physics is rarely a solitary subject; it is collaborative and takes trial and error. Active learning encouraged this and helped us learn more than physics; it taught us how to problem solve. Regardless of your discipline, that is a valuable skill.

Physics as a Language: How One Can Learn Once and Forever
Mira Zineddin
Class of 2025, Biomedical Engineering major
(Spring 2022 PHYS1425 student, now PHYS2415 TA)

It would be crazy if a Spanish class never practiced speaking Spanish, right? Much like Spanish, physics is also a language—one that communicates how the universe works. It’s not enough to only read about it in a textbook or watch a PowerPoint slide. We need time to be actively guided through applying these concepts. This is similar to how you’d start with basic sentences before writing paragraphs when learning a language. What active learning aids us with is building a developed sense of physics, which allows us to apply our knowledge to every situation in the universe—not just memorizing equations so that we can pass exams. Eventually, most of these equations will be forgotten, leaving students only with the concepts that they genuinely understood. I am glad I chose the AL style and I gained a better intuitive understanding of physics that I can apply throughout my life.

Gaining Depth Through Collaboration
Lara Ojha
Class of 2025, Materials Science & Engineering major
(Spring 2022 PHYS1425 student, now PHYS1425 TA)

With 2 years of high school physics under my belt, Physics 1 for Engineers felt like a redundant requirement—something I just had to do. I happened to be registered for the “active learning” section—whatever that meant. But as I sat down at a circular table on the first day of class with what would become my new group, it became quickly obvious to me that my assumption could not have been more incorrect.

As it turned out, that group of peers became enthusiastic collaborators throughout the semester. The
Active Learning (continued)

weekly quiz problems were complex and not easily done on our own, which encouraged us to work together. This gave me, someone who enjoys physics, an opportunity to discuss physics with my peers, and to help guide students newer to physics through the problem-solving process. Students new to the material would follow along in the group process while confirming details of the concepts with us along the way. When someone got stuck, frustration was allayed when another person picked up where they left off, from a slightly different angle. By the end of our class period, everyone in my group had the confidence that they had participated in the journey to the correct solution, and gained a deeper understanding of why we were all studying physics in the first place.

The Power of Physics
Troy S. Meink
Class of 2025, Mechanical Engineering & Physics major, Data Science minor
(Spring 2022 PHYS1425 student, now PHYS1425 TA)

Physics, as the most fundamental physical science, presents a clearer image of the world around us, showing that the seemingly arbitrary mechanisms of everyday life are driven by the laws of nature. I’m double-majoring in mechanical engineering and physics. The why, with a focus on real-world applications, is something I always wanted to learn because it gives me a deeper understanding of my engineering work.

I think that is a strength of Active Learning in physics, both for myself and students in other majors. Weekly quizzes, though at first intimidating, became an integral part of the class structure. Spending more class time working on problems, both guided by the professor and in groups, gives students more practice with course concepts. In my experience, this not only helped in the retention of new concepts, but also left me better prepared to tackle similar application problems in my engineering coursework.

Organizing classes into groups of eight to nine students also offered benefits over a traditional lecture structure. These groups gave more opportunities to students who were struggling to find help. It can be nearly impossible for professors to touch base with all of their students and to provide guidance when needed. However, peer groups can act as a safety net better suited to helping members who need it. This system ultimately ensures students learn in what is arguably the best way possible, from each other.

New Faculty Profile

Jency Sundararajan

Jency Sundararajan is a native of the state of Tamil Nadu, India. She received bachelor’s and master’s degrees from Bharathidasan University and worked as a physics lecturer at Holy Cross College in her hometown of Trichy. She then came to US and obtained her master’s and PhD from the University of Idaho, Moscow ID. Her doctoral work centers on analyzing the opto-electrical properties of semiconducting nanowires and the variations in charge transport in hybrid nanostructures. She completed her postdoctoral research at the University of Washington, Seattle WA on the modeling of nanodevices for photovoltaic applications and nano-biosensor devices. Prior to joining UVa as an Assistant Professor, General Faculty, she was an Associate Professor of Physics at Missouri Southern State University, Joplin MO.

Jency’s research interests focus on nanodevice fabrication of semiconducting nanowire field effect transistor sensors using standard photolithography and e-beam techniques, and employing microfluidics for selective, sensitive, label-free detection of biological and chemical species. She is passionate about teaching physics in creative ways that facilitate learning, emphasizing better understanding of the subject matter by implementing learner-centered teaching techniques and active student participation. She is interested in making physics entertaining for all ages through hands-on activities and fun demonstrations. She is enthusiastic about promoting science and has been constantly involved in community outreach and science shows on/off campus and at local schools. She is associated with the Society of Physics Students (SPS) locally and nationally, serving as SPS advisor and Zone councilor respectively.

Jency is excited to join UVa Physics and looks forward to exploring new teaching techniques in large classrooms and getting involved in experimental research on semiconducting nanowires for sensing applications.
Research Highlight: PREX/CREX Measuring Nuclei

Allison Zec, PhD 2022

What does matter look like, and how does it behave on the smallest scales? This question may seem simple to ask, but it is certainly challenging to answer. Even the largest atomic nuclei are still extremely small, far too small to be seen by even the world’s most powerful microscopes. Additionally the physics that governs matter at the scale of atomic nuclei is far different than the physics we’re used to in our everyday lives. Therefore, we have to invent more subtle ways of measuring nuclei.

Particle scattering has been one of the most reliable ways of probing the physics of systems too small to be understood by conventional means. When particles scatter off each other the nature of the scattering tells us about the nature of the interaction happening between them, which yields important physics information. These particles will interact via one of the forces of nature: the strong nuclear force, the weak nuclear force, or the electromagnetic force. Atomic nuclei are composed of a number of positively-charged protons and electrically neutral neutrons, and the number of neutrons relative to protons for stable nuclei gets larger as nuclei get heavier. Protons are sensitive to the electromagnetic interaction, but neutrons are not, making the neutron density in nuclei impossible to probe from a purely electromagnetic interaction. However, neutrons are sensitive to the weak interaction, meaning that their density can be probed. There is a catch however: the weak interaction is much less powerful than its electromagnetic counterpart, making experiments to measure it quite technically challenging!

The PREX-II experiment, proposed by physics department members at UVa, is one such experiment designed to measure the neutron density of one nucleus in particular: lead-208, the heaviest known stable nucleus with 82 protons and 126 neutrons. Lead-208 is interesting because the excess neutrons in it are theorized to form a “neutron skin” around the outside of the nucleus, and this skin can be measured by measuring the neutron density. PREX-II employs a technique known as parity-violating electron scattering (PVES). PVES uses the unique properties of the weak interaction to measure an asymmetry in the scattering of electrons off nuclei. PREX-II found that the neutron skin thickness in lead was 0.283 femtometers, a measurement which is 1,000,000 times smaller than the diameter of a hydrogen atom! Lead-208 is interesting for another reason: the behavior of the nucleus of lead is quite like that of neutron stars. PREX-II can then function as a terrestrial laboratory to study the behavior of extremely dense nuclear matter contained within neutron stars. PREX-II’s results are then consistent with observations taken from the NICER telescope aboard the international space station.

The PREX-II results represent an important milestone in nuclear structure measurements, and also represent a significant leap forward in PVES experimental technology. We hope to use this experience to develop PVES experiments with an even higher level of precision in the future.
Bradley (Brad) Cox received his doctoral degree in elementary particle physics from Duke University in 1967. Brad’s career spans much of the development of the Standard Model (SM) of particle physics and intercepts several of the major achievements guiding our understanding of the elementary particles. Following his PhD, he served as a Captain in the US Army and also as Assistant, and later Associate, Professor of Physics at Johns Hopkins University. Brad’s earlier research interests led him to experiments at Brookhaven National Laboratory and Stanford Linear Accelerator. In the early ’70s he began a long association with experiments at the Fermi National Accelerator Laboratory (Fermilab) as the lab was just coming online and transforming a patch of the Illinois prairie into a world-renowned center for research. His early work included topics related to direct photon production and hadronic interactions at high energy, in essence improving our understanding of the nascent quark-parton model that was being newly explored at this time. Brad’s early experiments also set the stage for his continuing interest in the topics of heavy quarks and CP violation, which relates to subtle differences observed in the behavior of matter and antimatter and ultimately underlies the formation of our matter-dominated universe. Brad later moved from Hopkins to join the Fermilab scientific staff and served in numerous leadership roles as spokesperson of multiple experiments and in laboratory technical and physics divisions. In 1988 Brad joined the UVa faculty as Professor of Physics as the founding member of the UVa High Energy Physics Group. Over the next decade this experimental group would grow to five faculty members. In his early days at UVa Brad was a leader of one of the proposed experiments for the Superconducting Super Collider, the most powerful particle collider project ever attempted. Progress in science rarely looks like a straight line and unfortunate circumstances led to the cancellation of the project, essentially ceding the future of the energy frontier to the Large Hadron Collider (LHC) at the CERN laboratory in Switzerland. Rebounding from this blow to the US strategy, Brad shifted efforts and led the UVa team’s work on the new KTeV experiment at Fermilab, contributing to precision studies of CP violation and rare decays of the “strange” Kaon particles. This experiment made the first statistically significant observation of “direct” CP violation, confirming a question arising in the description of the weak nuclear interaction that had eluded discovery for 50 years. The next step in his scientific career was to focus on heavy quark studies with a new Fermilab experiment at its Tevatron collider, with UVa winning a major detector construction project under Brad’s leadership. Lightning struck again with circumstances in the early 2000s leading to various redirections from Washington, effectively closing off this direction of research for the US program at the time. Those of us who know Brad also know that a few megavolts, brickwalls, or wild horses are not going to hold him back for long. In 2007 Brad led UVa’s entry to the CMS experiment at the CERN LHC with a strong involvement in the EM calorimeter system which would be instrumental in the discovery of the Higgs boson in 2012 and leading to the Nobel Prize for François Englert and Peter Higgs in 2013, coincidentally also 50 years after their theoretical predictions. Brad’s contributions to its discovery at the LHC resulted in numerous honors such as the Distinguished University Scientist (UVa), Outstanding Virginia Scientist, and the Jesse Beams Award for significant physics research from the American Physical Society (APS). Perhaps this proves adversity is the mother of discovery! Brad’s numerous recognitions over the course of his career include fellow of the APS and the American Association for the Advancement of Science, and his service to the community includes numerous contributions to the work of the APS, laboratory and agency committees, and organization of national and international conferences and study groups. Brad’s recent interests include the pursuit of Supersymmetric extensions to the standard model and studies of new detector systems to enhance the capabilities of LHC and future experiments. We hope that lightning will not strike a third time, but if it does, look out!
The pyramids of ancient Egypt and of pre-Hispanic Mesoamerica have fascinated people since the cultures that built them vanished. How were they built? What were they used for? Are there unknown internal substructures, perhaps hidden chambers that have yet to be discovered? In the ‘heroic’ age of pyramid explorations, adventurers and grave robbers often demolished their way into the pyramid interiors, usually causing irreversible damage. Entrance by destruction is no longer possible since preserving these unique structures is paramount. Other means of exploration need to be used. One method is to use cosmic-ray muons to effectively perform a tomographic exploration of the structures, probing their interiors using techniques similar to that done on medical patients with a CAT scanner. Professor Dukes and his team members — research scientist Ralf Ehrlich, technicians Eric Fernandez and Wayne Farrell, and undergraduate student Sydney Roberts — are spearheading two efforts that aim to unlock possible secrets of these pyramids’ internal structures using cosmic-ray muons as a probe.

His team has been working with groups at Cairo University, the Oriental Institute at the University of Chicago, and Fermilab to design a detector for decisively determining if voids exist in the Great Pyramid of Khufu in Giza, Egypt. The detector concept is based on the design of the Cosmic Ray Veto that is being fabricated at UVa for the Mu2e experiment at Fermilab. However, significant improvements to the design for the purposes of performing cosmic-ray muon tomography have recently been made at UVa. Ehrlich has been leading the simulation effort needed to determine the detector parameters and expected resolution in finding hidden voids.

Receiving approval to mount the needed large detector in positions around the perimeter of the pyramid of Khufu, as well as securing the funding needed to build it, will be a long process. Hence, Dukes’ team turned their efforts to the much smaller Temple of Kukulcán (El Castillo) at Chichén Itzá, which needs a much more modest detector. The Temple of Kukulcán is the largest pyramid in Chichén Itzá. Since excavations began exploring it in the 1930s, archeologists have found two additional buildings nested beneath its outer structure, suggesting it is a composite of three separate substructures. The state-of-the-art detector we have designed will allow its interior to be probed with great precision. Dukes’ team is collaborating with groups from two US Department of Education-designated minority-serving institutions in Chicago: Chicago State University, a predominantly black institution, and Dominican University, a Hispanic-serving institution. These two groups have received funding from the National Science Foundation for this effort. Dukes and Roberts applied and received funding this spring from the Jefferson Trust for the fabrication of a prototype detector. The collaboration has been augmented by Fermilab scientists and a local Mexican team that includes Menchaca Rocha, Chichén Itzá’s chief archaeologist, and the director of Frecuencia Cero Technology for Conservation, archaeologist Eduardo Pérez de Heredia. This past spring a prototype detector was fabricated at UVa by technicians Fernandez and Farrell. This summer it was brought to Fermilab by Ehrlich to be tested. Ehrlich and undergraduate physics major Roberts have been analyzing the data. In concert with those efforts, over spring break Dukes and Roberts travelled to Chichén Itzá along with other members of the collaboration, to make a survey of the site and some preliminary measurements. The final design of the detector is well underway with plans to install it into the interior of the Temple of Kukulcán next year.
Honors and Awards

Undergraduate Students

UVa’s SPS chapter was named an SPS Outstanding Chapter for the eighth straight year.

John Leondaridis was elected to Phi Beta Kappa.

Philip Velie has been selected as a runner-up for the National Outstanding Undergraduate Research Award.

Theo O’Neill won an Astronaut Scholarship.

William Musk won the Physics Community Leadership Award.

Alex Emmert, Dawn Ford, Charlotte Hoelzl, Bejoy Sen and Kai Vylet won Deaver Scholarships.

Gracemarie Buehlmann, Michael Stepniczka and David Winters won the outstanding undergraduate major award.

David Garwood and Michael Stepniczka won the Stephen Thornton Award in Physics Undergraduate Research.

Graduate Students

Hunter Presley won the Department of Energy’s Office of Science Graduate Student Research (SCGSR) Fellowship.

Miller Eaton won the 2022 Outstanding Graduate Research Award in Physics.

Faculty

Brad Cox, Bob Hirosky, and Chris Neu won a Research Collaboration Award from the University of Virginia Research Achievement Awards committee.

Despina Louca won a Distinguished Researcher Award from the University of Virginia Research Achievement Awards committee.

Despina Louca was elected a Fellow of the Neutron Scattering Society of America (NSSA).

Xiaochao Zheng won a UVa Student Council 2022 Teaching Award.

Thank You!

We greatly appreciate your continued support of the Deaver Scholarship Fund, general pledges and new initiatives. For additional information, please contact:

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