TUNL

TRIANGLE UNIVERSITIES NUCLEAR LABORATORY

2022 Newsletter

Spring Edition

From the TUNL Director by Robert Janssens

This first newsletter is the brainchild of the TUNL Committee on Climate. The plan is to have two such letters a year with the aim to keep the TUNL community informed of major successes in our research enterprise as well as of changes in operations, in personnel, etc.

The last couple of years have been particularly challenging for all of us because of the pandemic. We can only hope that we are getting closer every day to the time where we can all get together: what a celebration this will be! Because, indeed, we have much to be grateful for. COVID-19 may have slowed progress some, but research has continued, PhD theses have been defended, papers have been written, new projects have seen the light of day and others are on the horizon.

This is a good time to re-dedicate ourselves to the mission of the Laboratory. Here is the way the TUNL Scientific Steering Committee defined this mission in our most recent briefing with our sponsors in the DOE Office of Nuclear Physics

"Continue the TUNL approach of a synergistic use of accelerator and non-accelerator techniques to tackle the most urgent nuclear physics problems while continuing to educate and train next generations of a diverse scientific workforce"

I hope that you will all join me in the next phase of the TUNL adventure. It has the potential to be the best and most exciting one yet! Stay tuned...

TUNL Climate Committee

The TUNL Climate Committee (TCC) was formed in the summer of 2021 and has been meeting weekly since then. Its members are Alex Crowell (Duke), Matt Green (NCSU), Reyco Henning (UNC), Diane Markoff (NCCU), and Robert Janssens (UNC, ex-officio). Our first major activity was to propose and organize the two virtual “TUNL Days” over Zoom to facilitate a greater sense of community. During these TUNL days we were treated to presentations by both faculty and staff, introducing themselves and the diverse and rich physics program at TUNL. Both sessions were well attended with 147 individuals being present at the first TUNL day gathering! The TCC also conducted an anonymous survey of the TUNL community and is drafting a report based on the comments received. Finally, we drafted an updated Code of Conduct that has now been implemented. Looking forward, we hope to continue fostering a greater sense of community with more TUNL days, some possibly at the other Consortium universities. We are also putting out the first TUNL newsletter (this one!) and exploring options for an APS Bridge-like program between NCCU and the other Consortium universities. This list is not exhaustive, and we are always eager to listen to new ideas or any concerns you may have. Feel free to contact any members of the TCC if you have something you’d like to share.

- **Reyco Henning** on behalf of the TUNL Climate Committee

TUNL Seminars

Following a pause due to COVID-19, the TUNL seminar series resumed in Fall 2021 in a new, hopefully temporary, remote format. We hosted speakers on a wide range of topics including microanalytic isotopic analyses of meteoric presolar grains, neutrinos as tools for nuclear monitoring, and beta-decay measurements of ultra-cold neutrons. One highlight was a two-week celebration of the 25th anniversary of gamma production at HIGS, featuring stories from TUNL's rich history.

In Spring 2022, the TUNL seminar series will continue with exciting talks on the future of the Facility for Rare Isotope Beams, potential hints of a sterile neutrino from the Baksan Experiment on Sterile Transitions, and outreach with the CosmicWatch program, among other topics.

The TUNL seminar series has resumed on Thursdays at 3:30 beginning February 10.

- **Julieta Gruszko**, on behalf of the TUNL Seminar Committee (along with Phil Barbeau, John Kelley, Richard Longland, and Diane Markoff)

Student Achievements

- **Peifan Liu** defended his dissertation entitled "Experimental Study of Structured Light Using a Free-Electron Lase Oscillator." After graduation, Peifan joined the Advanced Photon Source at Argonne National Laboratory as a postdoctoral fellow. He also has two first author publications: (1) P. Liu, *et al.* "Phase retrieval for short wavelength orbital angular momentum beams using knife-edge diffraction," Opt. Commun. **474**, 126077 (2020). (2) P. Liu, *et al.* "Transverse mode analysis for free-space laser beams using Bayesian analysis," Appl. Opt. V. **60**, pp. 3344 (2021). The second paper was selected as an Editor's Pick.
- **Sam Hedges** successfully defended his dissertation on "Low-Energy Neutrino-Nucleus Interactions at the Spallation Neutron Source." He has taken a postdoctoral position at Lawrence Livermore National Lab in the Nuclear and Particle Physics group.
- **Tyler Johnson** was awarded the "Best Talk" for the second year in a row at the annual DOE NNSA University Program Review for his talk "Developing a Neutrino-Induced Nuclear Fission Detector".
- **Connor Awe** successfully defended his dissertation on "Novel Technologies for Neutrino and Dark Matter Detection". He is taking a position at SRI International in Boulder, CO.

Peifan Liu

Sam Hedges

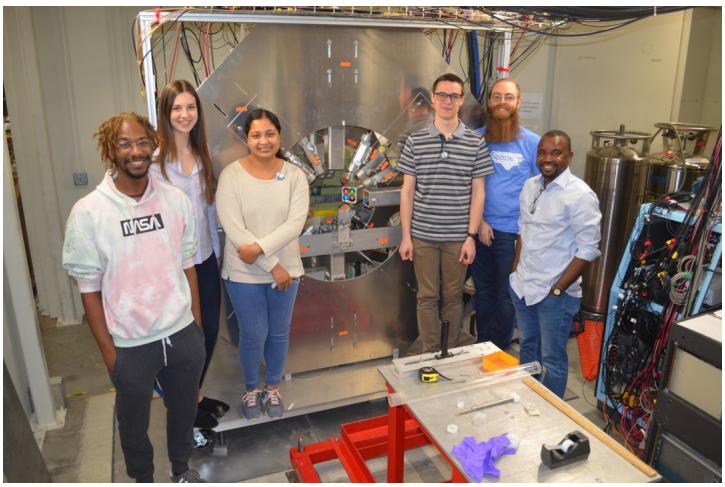
Tyler Johnson

Connor Awe

Research Highlights

- This was a productive Fall for the COHERENT experiment, who submitted 6 papers to journals. The topics included new Coherent Elastic Neutrino-Nucleus Scattering results; constraints on Dark Matter; Measurement of Backgrounds; and calibrations of detectors. The collaboration is playing a very active role in the Snowmass process, with **Phil Barbeau** and **Kate Scholberg** as Frontier conveners, and many other collaboration members as topical group conveners.

- During the past year and a half, the nuclear structure group at TUNL assembled and installed a powerful new detector system for use in conjunction with the γ-ray beams provided by HIγS. The Clover Array, which comprises eight large volume high purity germanium (HPGe) detectors of the clover type (4 crystals per cryostat make up one detector) and 12 Cerium Bromide ($CeBr_3$) scintillators, is instrumented with digital electronics. Since the installation, over eight different experiments have been successfully carried out, with many more scheduled to be performed. The array has met all performance expectations and was recently featured in Innovation News Network: https://www.innovationnewsnetwork.com/nuclear-structure/10491/



- An extensive study of the structure of ^{62}Co and ^{66}Zn was undertaken at the ATLAS facility at Argonne National Laboratory using the Gammasphere multidetector array and the Fragment Mass Analyzer. The level structures of both ^{62}Co and ^{66}Zn were considerably extended. In ^{62}Co, level sequences built on states with single-particle character were observed and interpreted as excitations within the *pf* shell. In addition, two rotational-like sequences of dipole transitions were also observed. These were interpreted as candidates for magnetic rotation. In ^{66}Zn, the previously observed low-spin structure was confirmed and, a new rotational sequence comprising quadrupole transitions was observed. This sequence shares characteristics with previously observed superdeformed bands in the A=70 mass region. Compared to the low-spin sequences, which are mostly neutron excitations, these superdeformed *bandlike* structures are shown to be dominated by proton excitations into the $g_{9/2}$ and $d_{5/2}$ deformation driving orbitals. Manuscripts reporting these observations are being prepared for publication.

- The MAJORANA DEMONSTRATOR, a search for neutrinoless double-beta decay, completed data-taking in 2022. This brings to a successful end a program that was initiated at TUNL 20 years ago. Members of TUNL are now looking to the future with the LEGEND program, a merger of the MAJORANA and GERDA Collaborations. LEGEND-200 is currently undergoing commissioning underground at INFN Gran Sasso National Laboratory (LNGS) in Italy, and the proposed LEGEND-1000 experiment was ranked at the top of the 2022 DOE Comparative Review of neutrinoless double-beta decay experiments. Faculty and staff at TUNL are taking leading roles on both efforts, setting the stage for an exciting program for the next decade and beyond.

Research Highlights (continued from p. 3)

- TUNL's recent publication of the D(p,γ)^{3}He rate [see **Jo Moscoso** *et al.,* ApJ **923**, 49 (2021)] completes our campaign of improving the thermonuclear rates for all of the key nuclear reactions that take place in the early universe. Our results are obtained using a hierarchical Bayesian statistical model. Its application to reaction rates has been pioneered at TUNL. Using our new results, we find significant tension between the predicted and observed primordial deuterium abundance. Therefore, besides the well-known cosmological ^{7}Li problem, we may have uncovered an additional "cosmological deuterium problem."
- The TUNL measurement of the ^{29}Si(p,γ)^{30}P reaction significantly improves predictions of the silicon isotopic ratios expected from models of classical novae. The key low-energy resonances were measured directly at LENA using our sensitive γ-γ coincidence spectrometer. The new reaction rate will facilitate the search for presolar stardust grains that classical novae may have contributed to the early solar system. The results have been submitted for publication [**Lori Downen** *et al.,* submitted to ApJ].
- As part of the DOE-funded VUV FEL mirror development program, we have recently demonstrated FEL lasing in a new VUV wavelength range from 168.6 to 179.7 nm, which set a new short-wavelength record for all FEL oscillators at 168.6 nm.
- Using newly developed 175 nm mirrors, we have produced circularly polarized gamma rays at 120 MeV, the highest energy photons generated at the HIγS facility. This success extends HIγS operation from 100 MeV up to 130 MeV, making it possible to conduct nucleon electromagnetic polarizability experiments in a new high-energy region at the HIγS facility.
- With the Duke FEL, we have demonstrated for the first time the formation of coherently mixed orbital angular momentum (OAM) FEL beams inside the optical resonator of an oscillator FEL, with several mixed modes produced at 458 nm. The operation of such an FEL in OAM modes paves the way for the generation of OAM gamma rays via Compton scattering.
- In Fall 2021, the NuDot Collaboration achieved two major milestones: installing the experiment's remote-operation calibration system and beginning detector commissioning. The calibration system, which features independent control of radial position, azimuthal angle, and inclination angle, allows a collimated beta-emitting source to be coupled to a small vial of liquid scintillator and used to test NuDot's Cherenkov direction reconstruction capabilities. This system will be used for all of the required data collection in the first two phases of the project. Detector commissioning is continuing, with initial data taking expected in Spring 2022. Once data-taking is complete, NuDot will be moved to TUNL for its second, liquid-filled phase of operation.

Research Profile—LENA II by Art Champagne

The Laboratory for Experimental Nuclear Astrophysics (LENA) was shut down in early 2019 and dismantled (fig. 1) in order to make way for a new facility, LENA II. This new laboratory will also feature two accelerators (fig. 2): an ungraded 230-kV ECR accelerator and a 2-MV Singletron accelerator (designed and built by High Voltage Engineering Europa B.V.). The latter is funded in part by a supplemental grant from the U.S. Dept. of Energy.

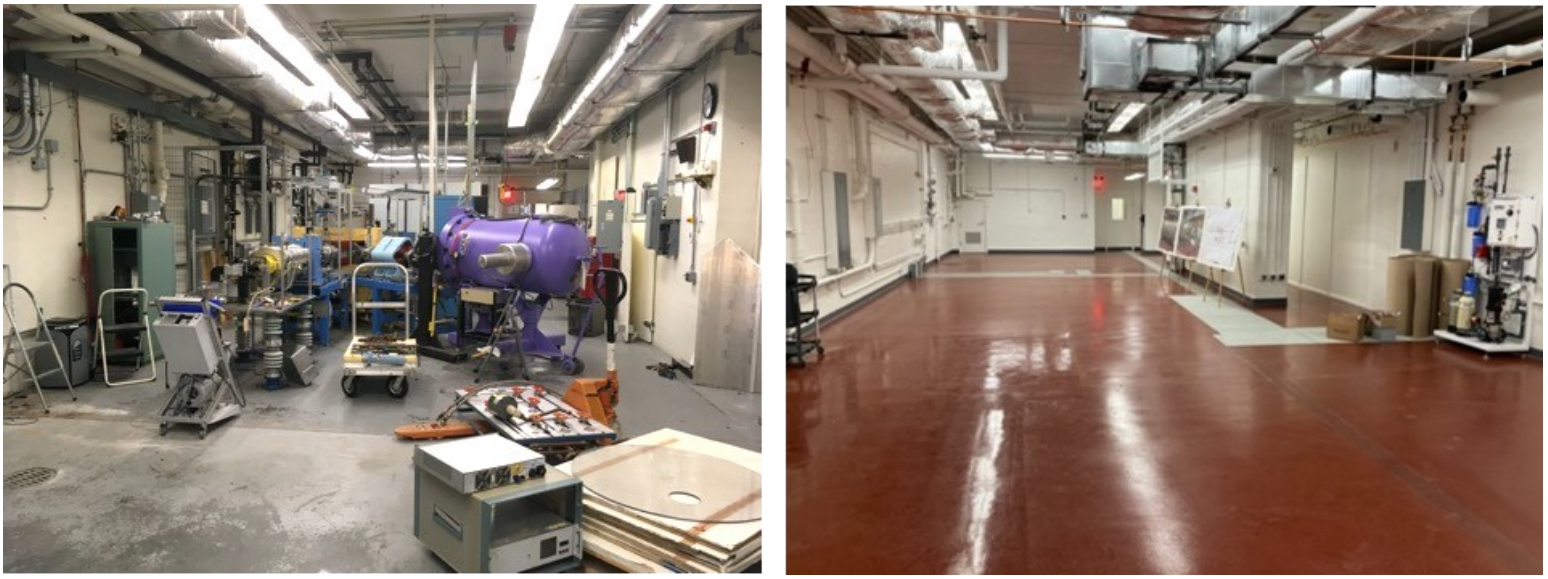


Fig. 1 (left) LENA being disassembled (March 2019). (right) The renovated laboratory space (Jan. 2021)

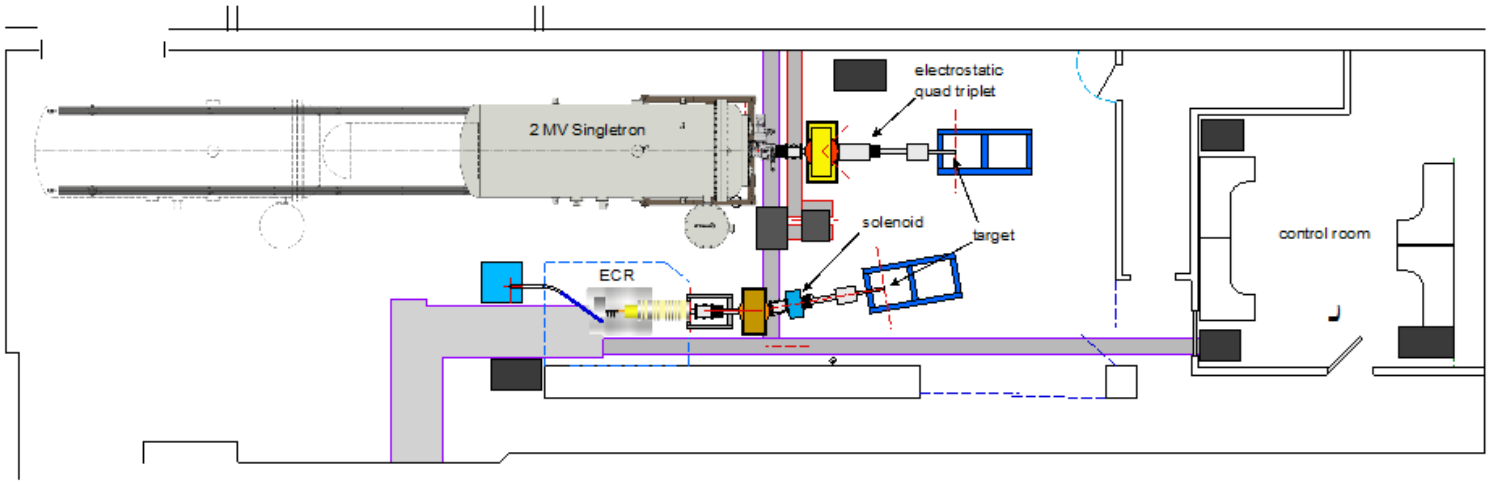


Fig. 2 Floorplan for LENA II showing the orientation of the ECR and Singletron accelerators.

The ECR accelerator produced proton beam currents of more than 2 mA on target, making it the most intense low-energy accelerator for nuclear astrophysics worldwide. The goal of the upgrade is to increase the beam current to about 20 mA. Although this amount of beam power (4.6 kW) is more than what most targets will tolerate, the goal here is to pulse the beam to about 1-2 mA equivalent DC beam. This will reduce cosmic and environmental backgrounds by a factor of 10-20. The ECR has been installed in the renovated laboratory space and is undergoing testing.

LENA II (continued from p. 5)

The Singletron accelerator (fig. 3) is an entirely new design, combining an ECR ion source with a fast beam-buncher/chopper system, producing high beam intensities (DC currents of 0.4–0.5 mA for E < 1 MeV and 2 mA for E > 1 MeV) with pulsing frequencies up to 4 MHz and pulse widths of 2 – 20 ns. Pulsing again can be used for background reduction or for neutron spectroscopy via time-of-flight. We expect delivery of the Singletron in early summer 2022.

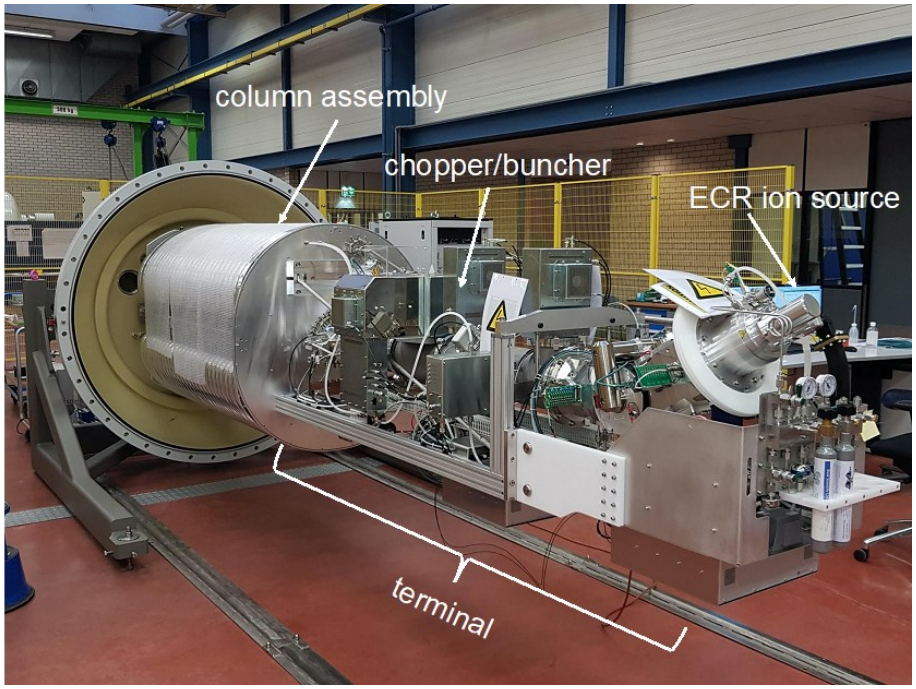


Fig. 3 The column structure of the Singletron accelerator. The beam from the ECR source passes through a 45° magnet into the chopper/buncher assembly.

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Welcome to our new TUNL Staff!

- **Mehreen Farooq—TUNL Staff Assistant (Located in TUNL 414)**

  Mehreen will be handling many administrative tasks for TUNL to include, purchasing office supplies, lab supplies, credit card clearings, packing slips, shipping, parking, being the main point of contact for deliveries and mail distribution, and key management. Mehreen will also be handling seminars and special events once COVID restrictions allow for such.

- **Eric Martin—TUNL Research and Development Engineer III (Located in FEL 108)**

  Eric comes to us from UNC Chapel Hill where he finished up a Postdoctoral position under the guidance of John Wilkerson. Eric brings much experience in the areas of KATRIN, MAJORANA, and LEGEND projects. Eric holds a PHD in Physics and a bachelor's degree in mathematics and physics. Eric is also a veteran of the United States Navy.

- **Edin “Ed” Vajzovic— TUNL Research and Development Engineer III (Located in FEL 111)**

  Edin comes to us with 26 years of engineering experience and most recently from Eaton Corporation where he has been their Senior Electrical Engineer for the past 11 years. Edin holds a master's degree in computer engineering, bachelor's degree in electrical engineering, and holds a patent for equipment enclosure fan controls system cooling.

In Memoriam: Professor Gary Mitchell

Gary Earl Mitchell, nuclear experimentalist and emeritus Professor of Physics at North Carolina State University, passed away on October 15. 2021. Prof. Mitchell joined the faculty at NCSU and TUNL in 1968 and retired in 2009 after a long and illustrious career in the fields of statistical nuclear physics and fundamental symmetries. Prof. Mitchell was a Fellow of the American Physical Society and received a number of awards during his career including the NC State Alumni Distinguished Graduate Professor Award, a Von Humboldt Foundation Senior Scientist Award, and the APS Jesse Beams Award.

Prof. Mitchell's lasting legacy is the nearly 60 graduate students whose PhD dissertations he directed or co-directed. In 2010, Prof. Mitchell was recognized with the Division of Nuclear Physics Mentoring Award for his commitment to the education and training of his students. The citation for that award reads:

"For his inspired, untiring, and selfless mentoring of an exceptionally large number of students, of diverse backgrounds, from their student days throughout their careers; for his ability to see the differing needs, interests, and skills of every one, tailoring his approach to each as a unique individual and a colleague; for his extensive pro-bono mentoring of many who were not his students, enhancing further his lifelong record of devotion to the educational process."

A Celebration of the Life of Dr. Gary Mitchell was held at NCSU on December 1, 2021 and attended by many former students and colleagues who remembered both his scientific and humanistic contributions.