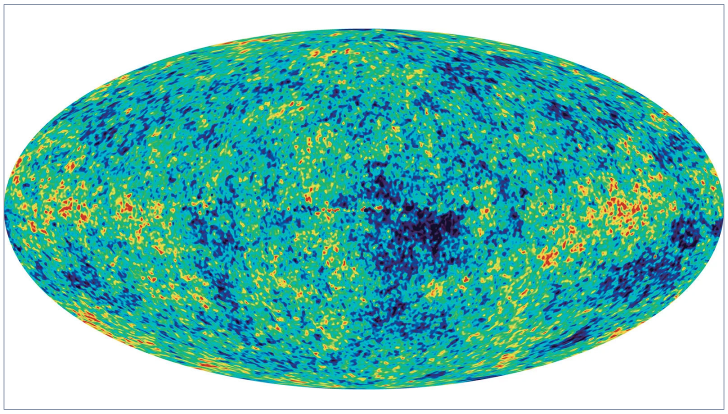
Yale

Wright Laboratory

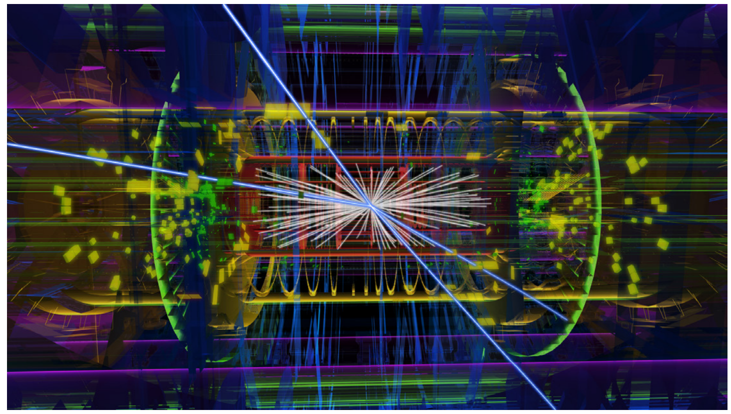
Exploring the Invisible Universe

Yale Wright Laboratory

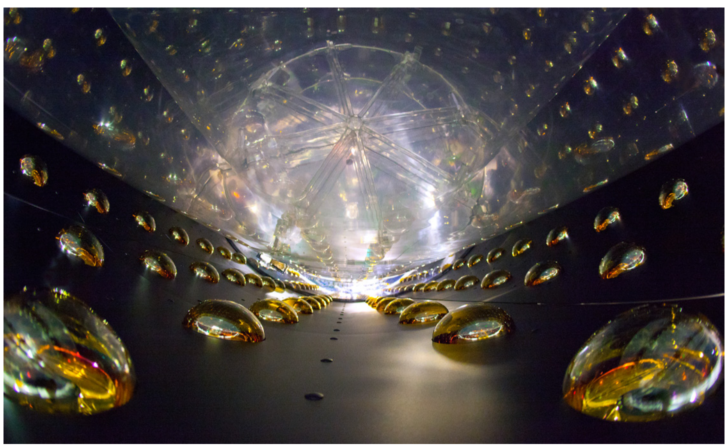
Research Areas



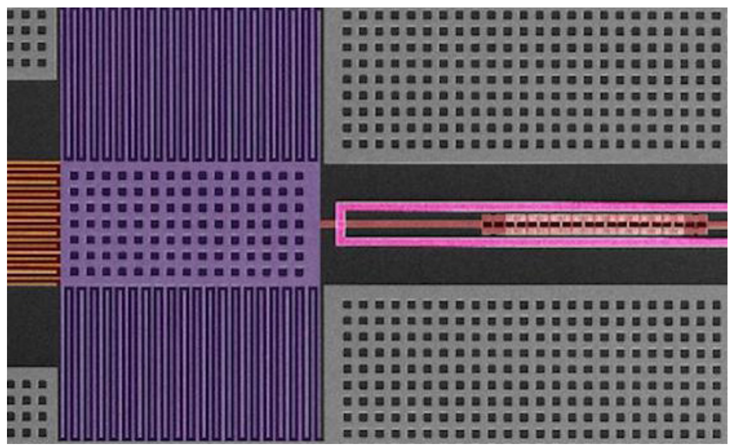
Astrophysics & Cosmology



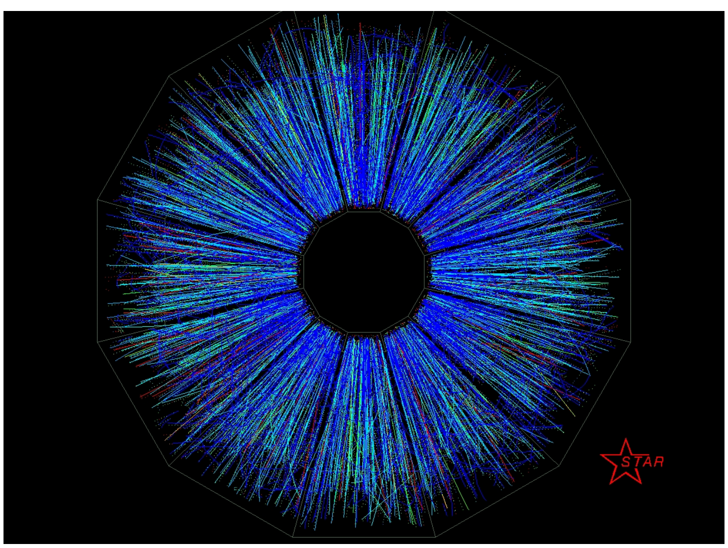
Elementary Particles



Neutrinos & Fundamental Symmetries



Quantum Science & Sensing



Relativistic Heavy Ions

Instrumentation

Studying elementary particles & the quantum realm

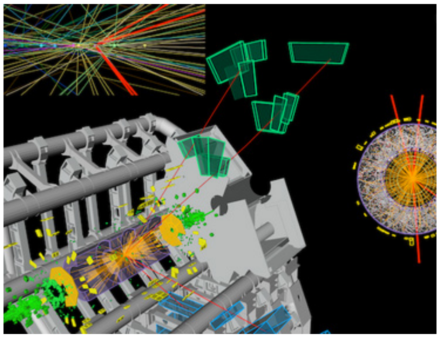
Keith Baker
D. Allan Bromley Professor of Physics

Keith Baker sets new limits on searches for physics beyond the Standard Model.

Baker was inducted into the American Academy of Arts and Sciences and is an American Physical Society (APS) Fellow. He also has received the Edward Bouchet Award from the APS; the Elmer Imes Award for Outstanding Research; the E. L. Hamm Sr. Distinguished Teaching Award; and the National Award for Teaching Learning and Technology. He was honored as a U.S. ATLAS Distinguished Researcher.

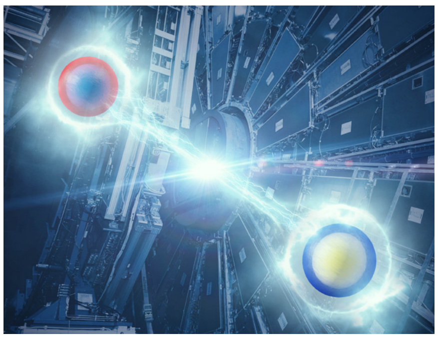
Baker has fulfilled his responsibility as a National Science Foundation Committee of Visitors (Particle Physics), and was a judge for the Yale College Porter and Field Prizes.

Baker is the academic editor and co-author of "Quantum Entanglement in High Energy Physics".



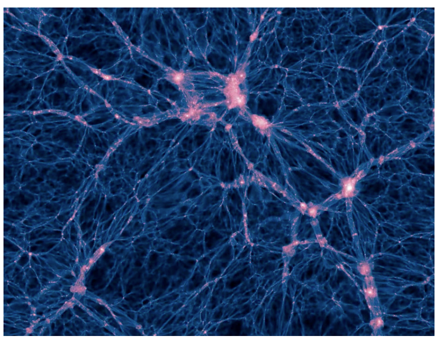
ATLAS

Keith Baker focuses on particle physics research at the energy frontier using ATLAS at the Large Hadron Collider in Switzerland, and precision studies at sub-eV energies. He helped build the ATLAS detectors and was part of the team that carried out the machine learning analysis in the discovery of the Higgs boson, the last elementary particle predicted in the Standard Model of particle physics. Baker is the Yale ATLAS team leader and Yale ATLAS Institute representative. He is also an online data quality transition radiation tracker shifter for ATLAS.



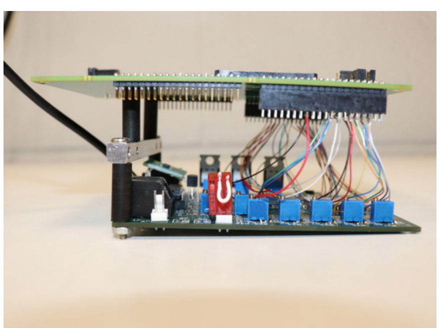
Quantum science & computing in high energy physics

The Baker group studies quantum information science in high energy physics, quantum entanglement, Bell's inequality, and entanglement entropy. The group demonstrates applications of machine learning, quantum computing, and quantum algorithms in physics analyses at high energies to better understand certain anomalies in data from high energy particle physics experiments.



The search for dark matter

Baker is searching for dark matter using the Higgs boson and in the form of axions, which are very low mass particles that are a theorized candidate for dark matter. To enable the latter, the Baker group will install detectors in the new Axion Longitudinal Plasma HAloscope (ALPHA) experiment, located at Wright Lab. ALPHA will search for higher mass axions by employing a novel axion detector called a plasma haloscope. ALPHA will comprehensively investigate how new experimental ideas using plasmas can be used to detect the axion.



Research and development for silicon sensors

The Baker group carries out research and development of monolithic CMOS (complementary metal oxide semiconductor) silicon sensors for use in high energy physics. This makes use of Field Programmable Gate Arrays (FPGA's) and software, as well as analysis programs and programming tools.

Investigating the expansion of the Universe

Charles Baltay
Eugene Higgins
Professor Emeritus

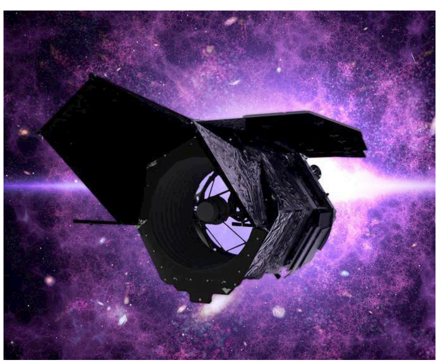
Charlie Baltay explores fundamental issues in particle physics, astrophysics, and cosmology. His research focuses on the nature of dark energy, a mysterious component that makes up three quarters of our universe that we know essentially nothing about. The Baltay group investigates dark energy via the study of distant supernova explosion events both from ground-based telescopes in the Andes Mountains in Chile and from the Nancy Grace Roman Space Telescope (formerly known as WFIRST).

LaSilla/QUEST Southern Hemisphere survey

Because the Hubble constant appears to be changing, scientists now theorize that the Universe is expanding and that there must be a new form of energy in the Universe, which scientists call dark energy. The Baltay group is working to resolve unexplained discrepancies in Hubble constant measurements using both Type Ia supernovae and RRLyra variables as “standard candles” to calibrate measurements.

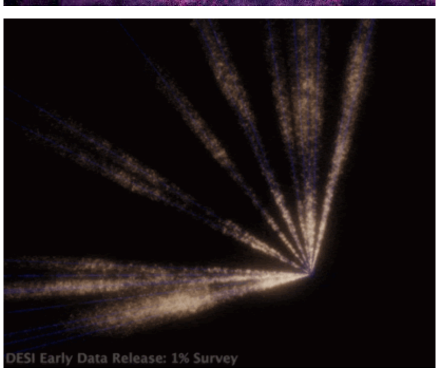
The Baltay group’s work has improved the precision of the Hubble constant measurement such that it is now better than the discrepancy. Furthermore, the group, including researchers from Yale Astronomy Department, has been able to detect traces of structure in the Milky Way galaxy that will lead to greater understanding of the history of the formation of the galaxy,

A new international collaboration, including the Baltay group, has assembled to execute a new five-year survey called La Silla Schmidt Southern Survey (LS4). The Baltay group will contribute to the upgrade of the Quasar Equatorial Survey Team (QUEST) camera—originally built at Yale and Indiana University and installed on the one-meter Schmidt Telescope in Chile—for LS4. QUEST will be optimized to follow up on transient objects that might be discovered in surveys conducted by larger telescopes, such as the Legacy Survey of Space and Time (LSST) at Rubin Observatory in Chile.



Nancy Grace Roman Space Telescope mission

Baltay and his collaborator Saul Perlmutter (U.C. Berkeley) have advised NASA for many years on the design and use of the Roman Space Telescope for a supernova survey that, when combined with data from Baltay’s southern hemisphere surveys, will provide important new information about the nature of the mysterious acceleration of the expansion of our universe and dark energy. Baltay will continue efforts to develop the survey in 2024. The telescope is expected to launch in 2026.



Yale Fiberview Camera

The Dark Energy Spectroscopic Instrument (DESI) on the Mayall telescope at Kitt Peak National Observatory in Arizona is designed to create a 3-D map of the sky that will allow researchers to measure the effects of dark energy on the expansion of the universe. The Yale Fiberview Camera—designed, built, and installed by the Baltay group at Wright Lab—is an integral part of the efficiency and precision of DESI. DESI recently released eight terabytes of data that includes nearly two million objects. The data has already led to a set of published papers that demonstrate DESI’s ability to accomplish its design goals.

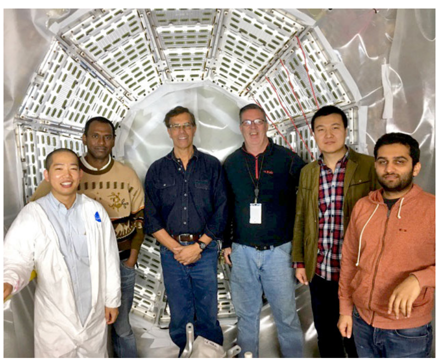
Recreating conditions of the early Universe

Helen Caines
Horace D. Taft Professor of Physics

Helen Caines focuses on understanding the behavior of nuclear matter under extremes of temperature and density.

Caines is an American Physical Society (APS) Fellow and a Fellow of the Institute of Physics, UK. In January of 2012, she was named APS Committee on the Status of Women in Physics Woman Physicist of the Month. She was also awarded the Engineering and Physical Sciences Research Council Advanced Research Fellowship, UK. Caines was the co-spokesperson of the STAR collaboration from 2017 to 2023.

Caines is an advocate for diversity, equity, and inclusion in STEM. Among the courses she has taught at Yale is “Being Human in STEM” and she is co-chair of the Yale APS Inclusion, Diversity, and Equity Alliance (APS-IDEA) team.



Relativistic Heavy Ion Group (RHIG)

RHIG, co-led by Helen Caines, Laura Havener, and John Harris, uses experiments that accelerate and then collide particles to recreate a primordial state of matter, the quark-gluon plasma (QGP). The QGP is a hot, dense, soup-like state of the fundamental particles of nature—predicted by the Standard Model of particle physics to have existed ten millionths of a second after the Big Bang—and is one of nature’s most extreme fluids. The group’s research focuses on measuring jets—the spray of high momentum particles from high energy particle collisions—and jet substructure to further understanding of the the properties and evolution of the QGP. RHIG is involved in the ALICE, STAR and ePIC collaborations.

Solenoidal Tracker at RHIC (STAR)

The STAR experiment is at the Relativistic Heavy Ion Collider at Brookhaven National Laboratory (BNL) in New York. Members of RHIG play a critical role in preparations and data-taking, including trigger coordination, shift leadership, and on-call detector expertise. As the co-spokesperson of STAR from 2017 to 2023, Caines led the successful completion of a multi-year data program called Beam Energy Scan II and the installation of a suite of forward-rapidity detectors. RHIG contributes to a diverse range of analyses, taking advantage of STAR’s large variety of datasets.

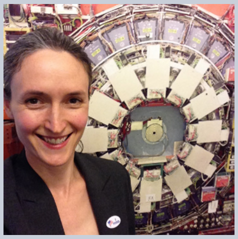
A Large Ion Collider Experiment (ALICE)

ALICE is a detector at the Large Hadron Collider at the European Organization for Nuclear Research (CERN) in Switzerland. Members of RHIG contributed to the construction and commissioning of an upgraded detector Time Projection Chamber using gas electron multipliers (GEMs). This upgrade allows ALICE to now produce data at a staggering rate of 3.5 terabytes per second, which is two orders of magnitude higher than before. RHIG members have contributed to various aspects of ALICE preparations and data-taking, and this expanded data set will be a primary focus of the RHIG ALICE program in the next few years.

Electron-Ion Collider (EIC)/Electron-Proton Ion Collider (ePIC)

RHIG has substantially increased its involvement in preparations for the future EIC, which will be built at BNL. The group has multiple ongoing research and development (R&D) projects, including calorimetry and tracking. Members of RHIG are working on charactirizing silicon photomultipliers (SiPMs) at Wright Lab and participating in test beam studies at CERN for the forward calorimeter of the ePIC detector. The group is also involved in R&D for gaseous tracking detectors.

Exploring the fundamental nature of the Universe



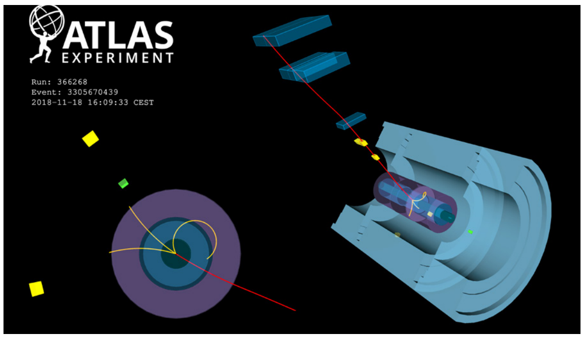
Sarah Demers
Professor

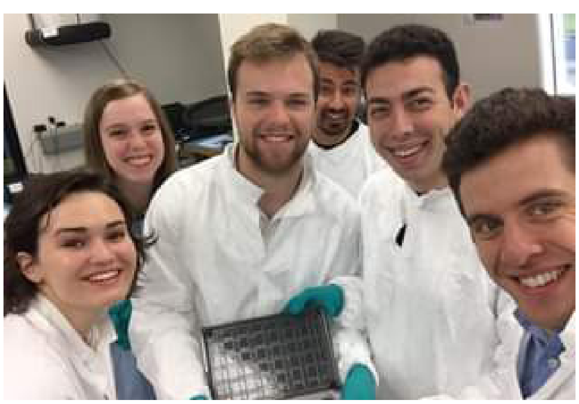
Sarah Demers uses tau leptons to probe for and characterize physics beyond the Standard Model with the ATLAS experiment and hunts for signs of new physics at the Mu2e Experiment.

Demers is a Fellow of the American Physical Society (APS), holds a number of leadership positions in both the ATLAS and Mu2e collaborations, and served on the national Particle Physics Project Prioritization Panel (P5).

Demers received the Yale Provost Teaching Award and the Yale Poorvu Family Award for Interdisciplinary Teaching. She is the Director of Undergraduate Studies for Yale Physics.

Demers is engaged with bringing science to the public realm and advocating for the equality of women in science through radio programs, op-eds, podcasts, talks, and outreach experiences.





ATLAS

The ATLAS experiment is a detector located at the Large Hadron Collider (LHC) at at the European Organization for Nuclear Research (CERN) in Switzerland.

The interactions in the ATLAS detectors create an enormous flow of data. To reduce the data volume, ATLAS uses an advanced trigger system to tell the detector which events to record and which to ignore. The Demers group develops the ATLAS trigger system and focuses on using tau leptons—a third-generation particle with a lifetime that is only a fraction of a second—to probe for and characterize physics beyond the Standard Model.

Demers has held many leadership roles in ATLAS. She has served on three ATLAS Editorial Boards and was appointed to the ATLAS Collaboration Board Chair Advisory group. She was a Large Hadron Collider Physics (LHCP) Conference Chair, and hosted the US ATLAS Summer meeting at Yale in 2023.

Demers is the ATLAS Deputy Data Preparation convener, was formerly a co-convener of the ATLAS Upgrade Physics group, was co-lead on the ATLAS Data Quality Group, and is the Chair of the US ATLAS Institute Board. With her leadership, Yale is an ATLAS Trigger and Data Acquisition Institute with design and validation responsibilities.

Muon-to-Electron Conversion Experiment (Mu2e)

Mu2e, located at Fermilab in Illinois, will search for the conversion of a muon directly to an electron in the field of a nucleus. This process, all but forbidden in the Standard Model, is enhanced in some compelling extensions to the Standard Model and a signal at Mu2e would be a clear sign of new physics. The Demers group is heavily engaged with development on the Mu2e trigger, including writing and optimizing many algorithms and leadership in the Trigger and Data Acquisition group. Demers is on the Mu2e publications board. She also led the "Engaging Non-Experts" group to help new people transition into the collaboration by developing computing tutorials and documentation.

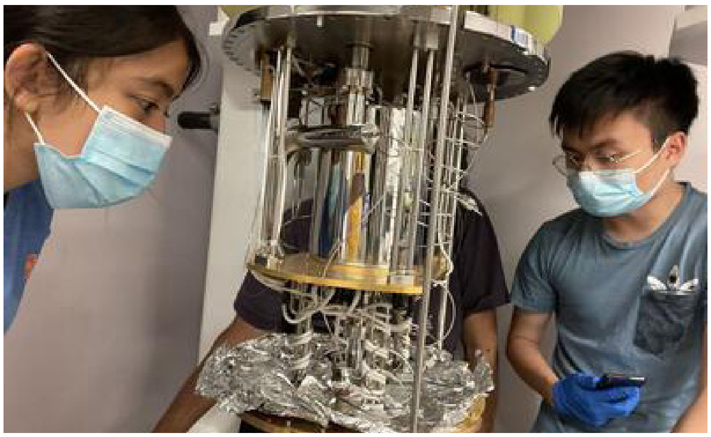
Probing the quantum realm

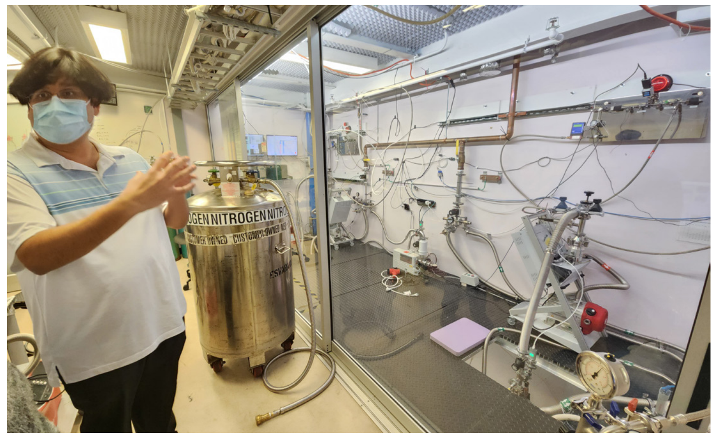
Jack Harris
Professor

Jack Harris explores the influence of quantum mechanics and topological effects upon the motion of macroscopic objects. He studies these phenomena in experiments that combine high-finesse optical cavities, ultrasensitive mechanical oscillators, and superfluid helium.

Harris is an American Physical Society (APS) Fellow and a Vannevar Bush Faculty Fellow. He was awarded the Arthur Greer Memorial Prize, the Defense Advanced Research Projects Agency (DARPA) Young Faculty Award, a Yale University Junior Faculty Fellowship, and the Sloan Research Fellowship.

Harris was a Lecturer for the Yale Warrior-Scholar Project and a mentor for the Research Experience for Veteran Undergraduates. He is the the faculty advisor for Queer Affiliated fRiends of physiKs (QuARK) in the Yale Department of Physics.





Single phonon detection using quantum acoustics

The Harris group is developing new technologies to control and study massive objects using light, and has been among the pioneers of the emerging field of quantum optomechanics. These quantum optomechanical sensors can detect tiny excitations of quantized sound (phonons).

The Harris group is exploring superfluid helium as a medium for use in ultraprecise and quantum-enabled sensors.

In one experiment, the group uses miniature, optical fiber-based cavities that are cooled in a dilution refrigerator and immersed in superfluid helium so that light and sound waves interact with each other. At the quantum level, this interaction allows a photon to occasionally emit or absorb a single phonon. When it does, the photon's wavelength is red-shifted or blue-shifted. The group collects light from the cavity, filters out all of the unshifted light, and passes only the shifted light to a single-photon detector. Each photon registered by this detector corresponds to the detection of a single phonon being added to, or removed from, the sound wave in the cavity. The ability to detect individual phonons, each with an energy in the microelectron volt range, is quite novel. The Harris group is exploring the possibility of using this type of control to prepare specific quantum states of sound that are particularly well suited to test the Standard Model of physics and to search for dark matter.

The Harris group is exploring similar scientific goals in a second experiment using a cavity formed out of superfluid helium that is free from any contact. The group achieves this by using magnetic levitation to suspend a millimeter-scale drop of helium in vacuum. The drop cools itself by evaporation, and the group has found that the drop's thermal, mechanical, and optical properties agree well with theory.

The Harris group is in the process of trying to trap photons in the drop's whispering gallery modes, with the goal of using single-photon and single-phonon techniques to study quantum features in the drop's motion.

These experiments are both table-top experiments supported by a range of collaborations, conducted in Wright Lab, and carried out by Harris group members.

By taking advantage of the unique mechanical properties of superfluid helium, sensors made by the Harris group might be able to enable new, ultra-sensitive searches for rare interactions from dark matter that complement other dark matter searches undertaken by Wright Lab researchers .

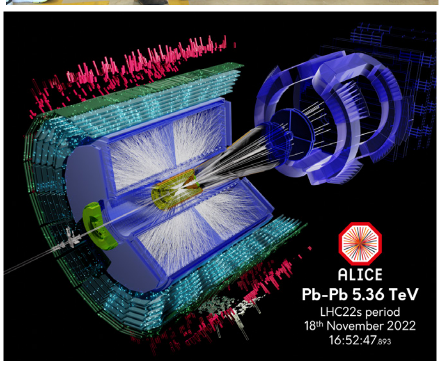
Recreating conditions of the early Universe

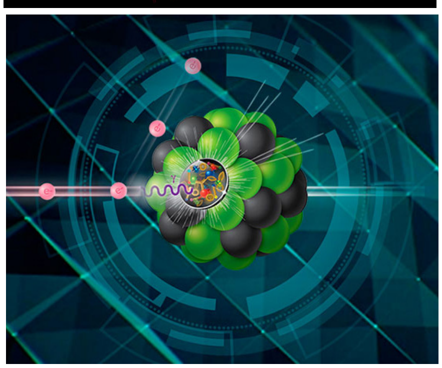
John Harris
D. Allan Bromley Professor Emeritus

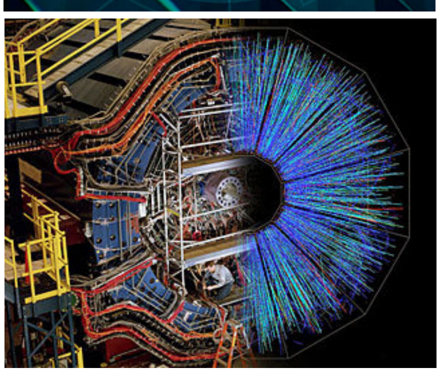
John Harris focuses on understanding high energy density quantum chromodynamics (QCD) created in relativistic collisions of heavy nuclei.

Harris is an American Physical Society (APS) Fellow. He was awarded the Alexander von Humboldt Senior Research Award in Frankfurt and was named one of the Top 40 Distinguished Alumni by Stony Brook University. He has served on and chaired many conference and workshop organizing committees, as well as Yale University committees. Harris is a member of the International Scientific Advisory Board for Romania and is the Chair of the Nuclear and Particle Physics Program Advisory Committee for Brookhaven National Laboratory.

Harris has organized and been a panelist for "Science Happy Hour at BAR" for public outreach.







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A Large Ion Collider Experiment (ALICE)

ALICE is a detector at the Large Hadron Collider (LHC) at the European Organization for Nuclear Research (CERN) in Switzerland. The ALICE detector was recently upgraded to allow for the production of two orders of magnitude more data. RHIG members have contributed to various aspects of the preparations and data-taking, and this expanded data set will be a primary focus of the RHIG ALICE program in the next few years. Harris served as the National Coordinator for the ALICE-USA Collaboration; Chair and Deputy Chair of the ALICE Collaboration Board; and on the ALICE Physics Board. He currently serves as an elected member of the ALICE Management Board.

Electron-Ion Collider (EIC)/Electron-Proton Ion Collider (ePIC)

RHIG has substantially increased its involvement in preparations for the future EIC, which will be built at Brookhaven National Laboratory (BNL) in Long Island, New York. The group has multiple ongoing research and development projects for the EIC, including particle identification (PID) detectors. Testing and characterizing photosensors for the proximity-focused ring-imaging Cherenkov (pfRICH) detector will be done at Wright Lab. Members of the group are also involved in software development for PID reconstruction.

Solenoidal Tracker at RHIC (STAR)

Harris has been an active member in the planning, conceptual design, construction, data acquisition, and physics of ultrarelativistic nucleus-nucleus experiments at the STAR experiment at BNL. He was the founding spokesperson for STAR from 1991 to 2002. Performing measurements in the different energy regimes at LHC and RHIC provides a complementary picture of the quark-gluon plasma.

Recreating conditions of the early Universe

Laura Havener
Assistant Professor

Laura Havener focuses on experimental high energy nuclear physics, studying quantum chromodynamics (QCD) using high-energy particle colliders. She specializes in exploring the complex structure of high-energy particles known to investigate the intricate nature of the deconfined state of QCD matter called the quark-gluon plasma (QGP).

Havener, along with other members of Yale's Relativistic Heavy Ion Group (RHIG), develops curriculum, activities, and experiments for local high school students with the Yale Pathways to Science program.

Relativistic Heavy Ion Group (RHIG)

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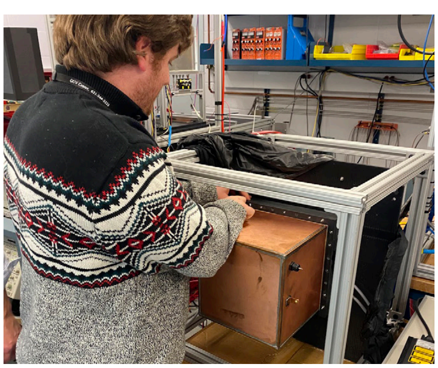

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Investigating the nature of neutrinos & dark matter

Karsten Heeger
Eugene Higgins Professor of Physics

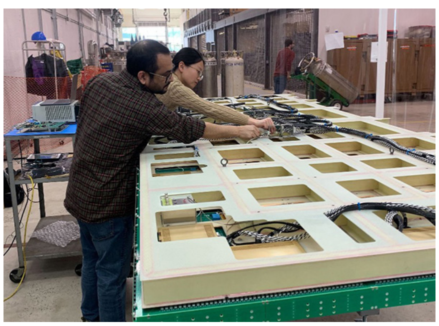
Karsten Heeger carries out cutting-edge experiments to study the properties of neutrinos, in search of rare event processes to solve some of the greatest mysteries of the Universe: What does the invisible Universe consist of? Why does the Universe have more matter than antimatter? What are the properties of neutrinos?

Heeger was awarded the 2016 Breakthrough Prize in Fundamental Physics and is a Fellow of the American Physical Society (APS). Heeger has served on numerous national and international advisory committees, including as Deputy Chair of the 2023 Particle Physics Project Prioritization Panel (P5) and as a member of the High Energy Physics Advisory Panel, the Nuclear Science Advisory Committee, and the Natural Sciences and Engineering Research Council. Heeger is the Chair of the Yale Physics Department and the Director of Yale Wright Laboratory.

Cryogenic Underground Observatory for Rare Events (CUORE)

CUORE, and its successor CUPID, both located in Italy, are searching for a previously undetected process called neutrinoless double beta decay. If such a process is observed, it would demonstrate that neutrinos are their own antiparticles, offering a possible explanation for why we live in a Universe of matter, not antimatter.

Heeger is co-spokesperson of CUPID, and, together with Reina Maruyama, co-Principal Investigator of CUORE. The Yale CUORE/CUPID team has been responsible for detector calibration, the study of cosmogenic backgrounds, double beta decay analysis, and the search for solar axions.



Deep Underground Neutrino Experiment (DUNE)

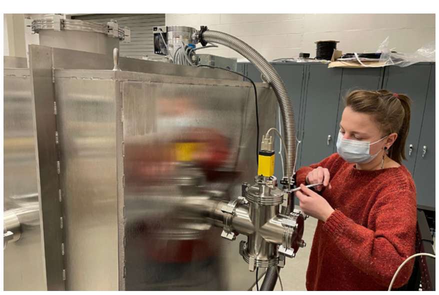
DUNE will send a high energy neutrino beam through the Earth's crust over a distance of 1,300 kilometers from Fermilab in Illinois to the Sanford Underground Research Facility in South Dakota to perform precision studies of neutrino oscillation. DUNE will study parameters of the matter-antimatter imbalance in the Universe and determine the ordering of neutrino mass states.

The Heeger group is responsible for the assembly of Charge Readout Planes at Wright Lab for the DUNE detectors and studying the detector response.

PRecision Oscillation and SPECTrum Experiment (PROSPECT)

PROSPECT is designed to make precision measurements of antineutrinos emitted from nuclear reactors, search for sterile neutrinos, and help develop technology for the remote monitoring of nuclear reactors for safeguard and non-proliferation.

PROSPECT was designed and built at Wright Lab in collaboration with Brookhaven National Laboratory, Lawrence Livermore National Laboratory, and other universities. PROSPECT operated at the High Flux Isotope Reactor at Oak Ridge National Laboratory in Tennessee.



Project 8

Project 8 utilizes a novel technique, dubbed Cyclotron Radiation Emission Spectroscopy, to perform a precision measurement of the yet unknown neutrino mass.

The Heeger group is performing research and development (R&D) on antenna and cavity prototypes, developing algorithms for event reconstruction and analysis, and performing simulations to optimize the detector resolution.

Searching for dark matter & testing symmetries

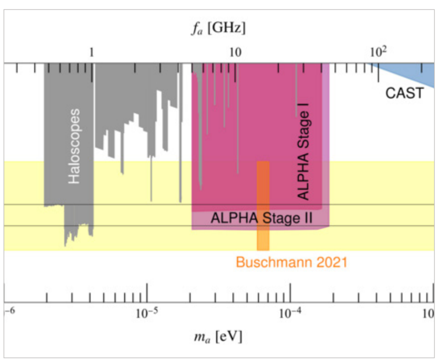
Steve Lamoreaux
Professor

Steve Lamoreaux studies the properties of the Universe and the fundamental laws of physics by use of small-scale tabletop experiments. He searches for axion dark matter by developing technologies for, building, and using haloscopes at Wright Lab; and probes ultracold neutron (UCN) physics. Lamoreaux uses his prior experience in quantum computing, cryptography, and the Casimir force to devleop advanced student laboratory projects.

Lamoreaux was awarded the Pipkin Award by the American Physical Society (APS) for precision measurement, three Los Alamos Distnguished Performance Awards, and the Henderson Prize for an outstanding dissertation by the University of Washington.

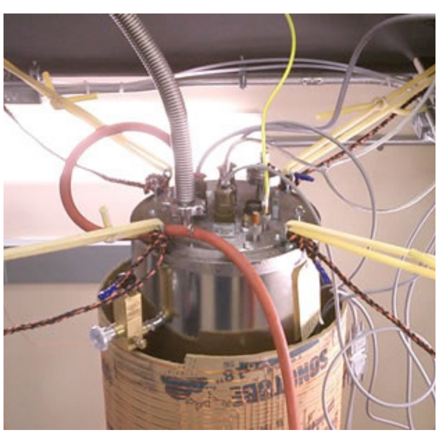
Haloscope At Yale Sensitive To Axion Cold Dark Matter (HAYSTAC)

The Lamoreaux group develops and uses experiments to search for axions, which are very low mass particles that are a theorized candidate for dark matter. HAYSTAC, which Lamoreaux co-leads with Reina Maruyama, is a tunable radiofrequency cavity resonator that serves to build up the axion signal. HAYSTAC uses photon sensors often used for quantum computing, as well as an innovative quantum noise squeezing technique to speed up the data taking of the experiment. HAYSTAC is located at Wright Lab, and the Yale team is responsible for systems engineering, cryogenics, and magnetics.



Axion Longitudinal Plasma HAloscope (ALPHA)

ALPHA will build on HAYSTAC's success and search for higher mass axions by employing a novel axion detector called a plasma haloscope. ALPHA, located at Wright Lab, will comprehensively investigate how new experimental ideas using plasmas can be used to detect the axion.



Electron Dipole Moment

Lamoreaux brings his expertise in magnets and magnetometry to support a neutron electric dipole moment (EDM) experiment at the Los Alamos National Laboratory in New Mexico. The goal of the experiment and the general search for EDM is to investigate the matter-antimatter asymmetry of the Universe.

Steve Lamoreaux and co-author Robert Golub, professor of physics at North Carolina State University, recently published "**The Historical and Physical Foundations of Quantum Mechanics**".

Find out more at: wlab.yale.edu/lamoreauxbook23

Exploring dark matter & the nature of neutrinos

Reina Maruyama
Professor

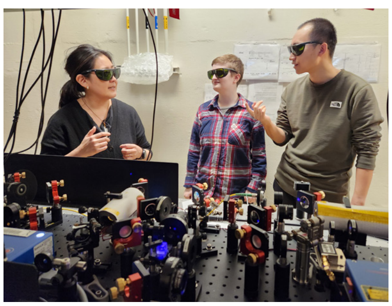
Reina Maruyama develops technologies and carries out experiments to probe the underlying physics of fundamental symmetries, origins of the Universe, and nature of neutrinos and dark matter. The Maruyama group uses techniques being developed in the fields of quantum sensors, atomic, nuclear, particle, and astro-physics to solve some of the greatest mysteries of the evolution of the Universe.

Maruyama is an American Physical Society (APS) Fellow. She was awarded the Sloan Research Fellowship, NSF CAREER Award, Yale Public Voices Fellowship, and the APS Committee on the Status of Women in Physics Woman Physicist of the Month (June 2013).

Maruyama was featured in Ingenium's Women in STEM initiative and is the co-leader of Yale's Asian Americans in STEM initiative.

Haloscope At Yale Sensitive To Axion Cold Dark Matter (HAYSTAC)

The Maruyama group develops and uses several experiments to search for axions, which are very low mass particles that are a theorized candidate for dark matter. HAYSTAC, which Maruyama co-leads with Steve Lamoreaux, is a tunable radiofrequency cavity resonator, which serves to build up the axion signal. HAYSTAC uses photon sensors often used for quantum computing, as well as an innovative quantum noise squeezing technique to speed up the data taking of the experiment. HAYSTAC is located at Wright Lab, and the Yale team is responsible for systems engineering, cryogenics, and magnetics.



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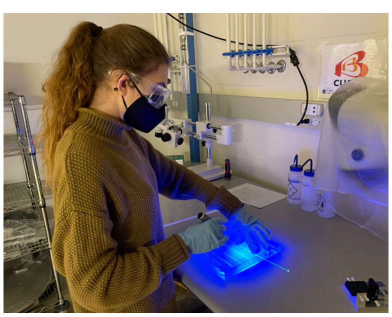
Rydberg Atoms at Yale (RAY)

To extend the mass range accessible by axion dark matter search experiments, the RAY group is is developing a single-photon detector for haloscope experiments, such as HAYSTAC and ALPHA. The detector is based on microwave transitions between highly excited Rydberg states in potassium atoms.

COSINE-100

COSINE-100 is a direct-detection dark matter experiment at the Yangyang Underground Laboratory in South Korea. The experiment is designed to test the DAMA/LIBRA Collaboration's claim that they have made a direct detection of dark matter, based on an annual modulation they observed in their data. COSINE-100 aims to understand the origin of DAMA's signal and search for their reported annual modulation signature by using the same target and detector material. Maruyama is the Principal Investigator of COSINE-100 and the scientific co-spokesperson of the experiment.



Cryogenic Underground Observatory for Rare Events (CUORE)

CUORE, and its successor CUPID, both located in Italy, are searching for a previously undetected process called neutrinoless double beta decay. If such a process is observed, it would demonstrate that neutrinos are their own antiparticles, offering a possible explanation for why we live in a Universe of matter, not antimatter.

Maruyama and Karsten Heeger are co-Principal Investigators of CUORE. The Wright Lab CUORE team has been responsible for the design, construction, and commissioning of the Detector Calibration System; analysis and simulation of data; and R&D.

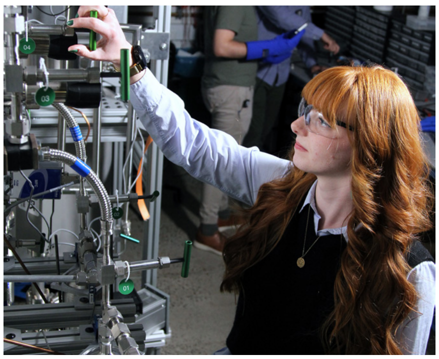
Probing the nature of neutrinos, dark matter, & gravity

David Moore
Associate Professor

David Moore develops new technologies and techniques aimed at answering some of the major outstanding questions in nuclear and particle physics about neutrinos, dark matter, the preference for matter over antimatter in the Universe, and the nature of gravitational interactions among quantum systems.

Moore received the Alfred P. Sloan Research Fellowship in Physics, the National Science Foundation (NSF) Early Career Award, the Lee Grodzins Postdoctoral Award at MIT, and the Mitsuyoshi Tanaka Dissertation Award in Experimental Particle Physics from the American Physical Society (APS).

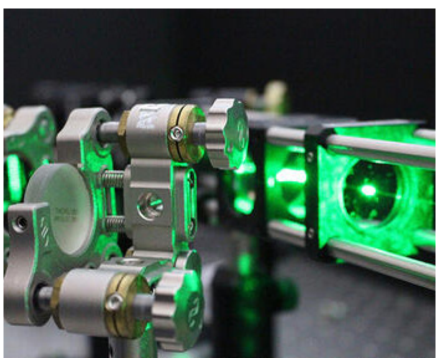
Moore is subsystem scientist for the nEXO photon detector, a member of the nEXO Executive Council, and an EXO-200/nEXO Collaboration Board member.



nEXO

The Moore group has been among the leaders of the development of large-scale liquid xenon detectors—such as the planned nEXO (next Enriched Xenon Observatory) experiment at SNOLAB in Ontario, Canada—to search for neutrinoless double beta decay. If this process is observed, it may answer why we live in a Universe made of matter, not antimatter.

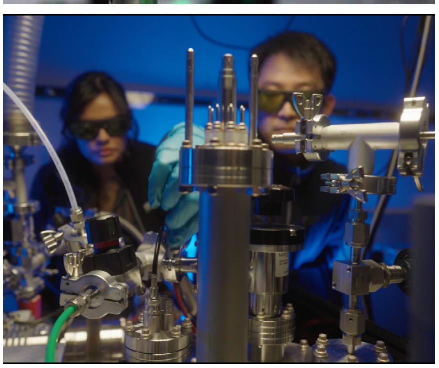
The Moore group is leading efforts to build photon detectors for nEXO and studying ways to capture xenon directly from the atmosphere to enable even larger, more sensitive detectors.



MAST-QG

Moore is collaborating on the MAST-QG (MAcroscopic Superpositions Towards witnessing the Quantum nature of Gravity) experiment to test whether gravity has a quantum nature by levitating tiny diamonds in a vacuum to see if they become entangled through their gravitational interaction.

The Moore group is using their expertise in precisely trapping nanoparticles in a vacuum to study the electromagnetic interactions between nanodiamonds.

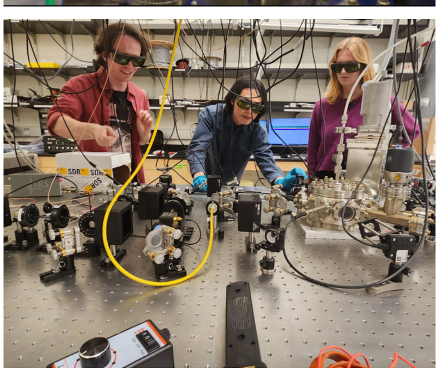


SIMPLE

SIMPLE (Search for new Interactions in a Microsphere Precision Levitation Experiment) is a small-scale tabletop experiment that fits in a laboratory at Wright Lab, yet is used to study interactions involving neutrinos; to test gravity; and to search for dark matter, quantum phenomenon, and new forces.

SIMPLE uses a technique called optical tweezers, in which a laser optically levitates, controls, and measures micron-sized spheres (microspheres). By measuring the motion of the microsphere, the group can precisely detect extremely tiny impulses, which are smaller than one-quadrillionth of the momentum transferred by a feather landing on your shoulder.

The Moore group has developed the world's most sensitive micron-sized force sensors, using them to search for dark matter interactions with the microspheres.



QuIPS

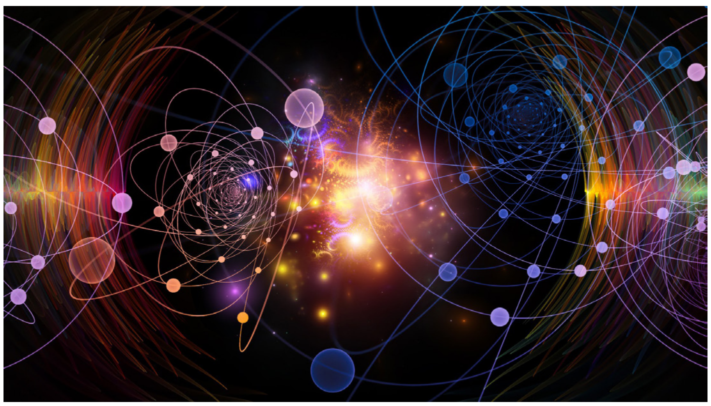
QuIPS extends the techniques used by SIMPLE to even smaller nanoparticles and will measure the momentum kick from a single nucleus decaying within a particle. QuIPS is located at Wright Lab and will enable new searches for otherwise invisible particles emitted in nuclear decays, such as sterile neutrinos.

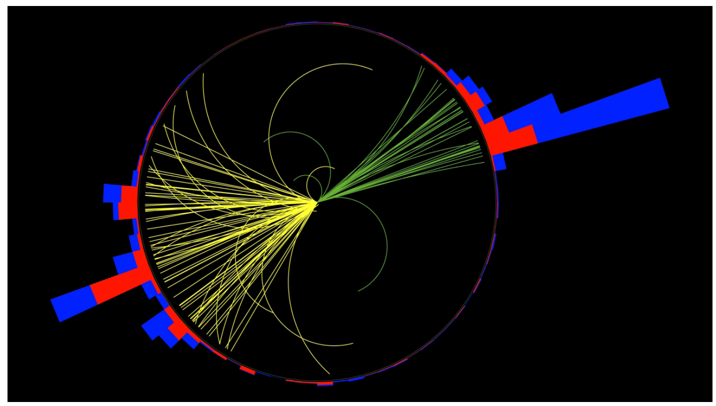
Developing new techniques for advancing discovery

Ian Moult
Assistant Professor

Ian Moult develops new theoretical frameworks and exploits theoretical advances to enable innovative new experimental strategies.

Moult was awarded the Wu-Ki Tung Award for Early-Career Research on Quantum Chromodynamics (QCD) for his "pioneering work on QCD energy correlators, including their all-orders factorization, multi-loop structure, phenomenological applications, and connections to conformal field theory". He was also awarded the 2017 J. J. and Noriko Sakurai Dissertation Award in Theoretical Particle Physics from the American Physical Society (APS).

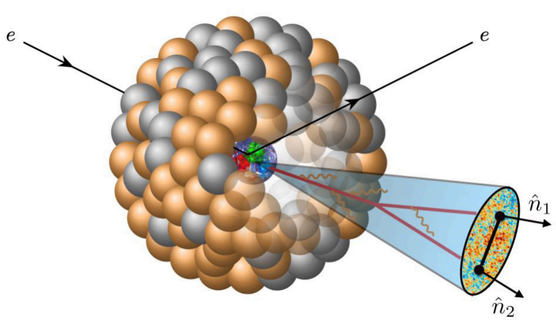


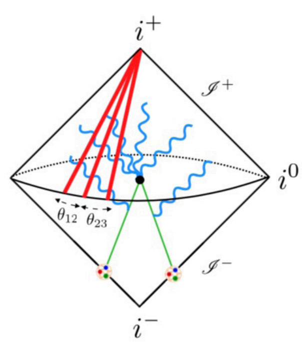


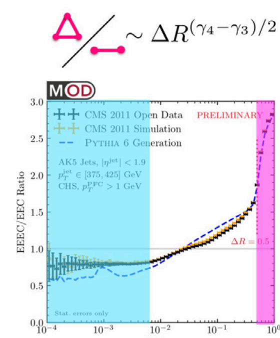
Quantum field theory

Ian Moult's research focuses on developing new techniques in quantum field theory for describing high-energy particle physics experiments, ranging from dark matter detection to the Large Hadron Collider (LHC). A common theme in his work is the use of effective field theories, which allow calculations relevant for complicated, real world experiments to be reduced to simpler, universal problems in quantum field theory.

Collider experiments and jet substructure







Moult has been developing new theoretical techniques to improve our understanding of real world collider experiments, with applications in particle and nuclear physics. He has played a leading role in the development of jet substructure, which takes advantage of subtle patterns in the structure of energy flow in collisions at the LHC to maximize the discovery potential for new physics and better understand the theory of the strong interaction.

A number of the approaches Moult introduced were first demonstrated in measurements by Wright Lab Relativistic Heavy Ion Group graduate students Andrew Tamis and Ananya Rai.

Investigating the beginning & expansion of the Universe

Laura Newburgh
Assistant Professor

Laura Newburgh studies the past 13 billion years of cosmic history through measurements of the Cosmic Microwave Background (CMB) and 21 cm hydrogen emission from faraway galaxies. Her work involves designing, building, and using instruments that go on radio telescopes around the world. The data from these instruments enable her to probe the nature of dark energy, dark matter, neutrinos, and cosmic inflation.

Newburgh received a National Science Foundation (NSF) CAREER award in 2018. She shared the 2022 Berkeley Prize with CHIME collaborators for breakthroughs in understanding Fast Radio Bursts (FRBs).

Newburgh frequently designs and carries out outreach programs for local schools in partnership with the Yale Pathways to Science program.

Canadian Hydrogen Intensity Mapping Experiment (CHIME)

CHIME is a radio interferometer telescope in Canada that is used to measure the expansion history of the Universe and discover insights about dark energy, a mysterious component that makes up approximately 72% of the energy density of the Universe and is causing the expansion of the Universe to accelerate. The Newburgh group uses a technique called holography to map the beam shape of CHIME. Understanding CHIME's standard beam shape is critical to be able to identify and remove emission from unintended sources.

Hydrogen Intensity and Real-Time Analysis eXperiment (HIRAX)

HIRAX is an interferometric array of 256 6-meter radio dishes in South Africa. HIRAX is designed to study high-redshift large-scale structure for a constraint on dark energy and transient science to understand the nature of Fast Radio Bursts (FRBs).

The Newburgh group is leading the development of techniques, hardware, and analysis to measure and map the HIRAX beam shape with a quadcopter drone.

Simons Observatory (SO)

SO is a new millimeter observatory that is designed to make the most sensitive measurements of the Cosmic Microwave Background (CMB)—light the Universe emitted when it was 400,000 years old. SO will consist of four new telescopes in the Atacama desert in Chile. The Newburgh group is part of the team commissioning SO. Newburgh leads the data acquisition and control group, mainly building software to control and acquire data.

Drone calibration

The Newburgh group is involved in R&D of techniques and equipment to map the beam shape of radio telescopes with a quadcopter drone. The Newburgh group has tested drone calibration in several U.S. locations; including Greenbank Observatory, Brookhaven National Laboratory, and Wright Lab.

The Newburgh Group has developed a radio telescope at Wright Lab that is used as a testbed for instruments, technologies, and measurement techniques they are developing to calibrate telescopes at observatories around the world.

Developing instrumentation & studying the Universe

James Nikkel
Research Scientist

James Nikkel is an experimental physicist who specializes in detector design and development for nuclear and particle astrophysics applications. Leveraging his varied experience and expertise, he created an instrumentation development program that serves research groups and interdisciplinary institutions across Yale's campus.

Dr. Nikkel has appointments in the Yale Department of Physics, the Yale School of the Environment, and the Yale School of Architecture, where he teaches a design and fabrication class.

Wright Lab Advanced Prototyping Center (APC)

Dr. Nikkel founded and supervises operations at the Wright Lab Advanced Prototyping Center (APC), which provides modern fabrication and design support for instrumentation development within the Yale community. Users include researchers, teachers, technicians, and artists from a variety of fields, including: medicine, physics, environmental science, and art restoration.

The APC group has experience with mechanical systems, electronics, fabrication, systems integration, and visualization. APC projects include creating the interior structure of a large model for the Yale Peabody Museum and developing a novel water analysis instrument for the Yale School of the Environment.

In addition, the APC provides one-on-one training and workshops in modern design and fabrication techniques for the Yale community.

Dark matter detection experiments

Dr. Nikkel has developed instruments for direct detection dark matter searches using noble liquids, including primary systems for the liquid argon-based DEAP/CLEAN projects, and the liquid xenon-based Large Underground Xenon experiment (LUX). He also designed mechanical components for the sodium iodide-based dark matter detectors in COSINE, located in an underground laboratory in South Korea, and for a potential upgrade to Dark Matter-Ice (DM-Ice), an experiment under two kilometers of ice at the South Pole.

Neutrino experiments

Dr. Nikkel led the design, fabrication, and deployment efforts of the radioactive source calibration system for the PRecision Oscillation and SPECTrum Experiment (PROSPECT) neutrino detector. This detector—built at Wright Lab and installed near a test reactor at Oak Ridge National Laboratory in Tennessee—was used to study nuclear processes and search for new species of neutrinos.

Dr. Nikkel also works on research and development to solve a variety of instrumentation challenges for Project 8, an experiment at the University of Washington that aims to measure the mass of neutrinos using radio wave emission.

The New Haven Harbor Living Laboratory, with collaboration of the APC, provides solutions to Earth's planetary challenges by developing and monitoring a local oyster reef. Read more at wlab.yale.edu/nhll23.

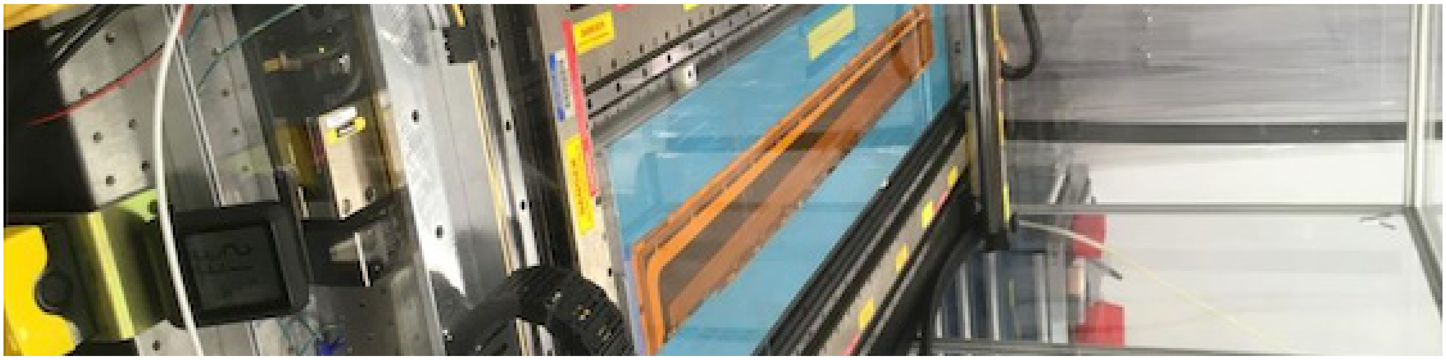
Exploring the fundamental nature of the Universe

Paul Tipton
Eugene Higgins Professor of Physics

Paul Tipton questions existing scientific models of the physical Universe and searches for new understanding of how the Universe works, discovering and characterizing new particles and searching for other phenomenon beyond the Standard Model of physics.

Tipton is an American Physical Society (APS) Fellow. He was awarded the National Science Foundation (NSF) Young Investigator Award, the United States Department of Energy (DOE) Outstanding Junior Investigator Award, and multiple teaching excellence awards.

Tipton was co-convener of the Collider Detector at Fermilab (CDF) Top and B Quark Physics Group, a member of the Physics Advisory Committee at Fermilab, and a member of the Editorial and Planning Committee for the journal *Annual Review of Nuclear and Particle Science*. He served as Chair of the Yale Department of Physics from 2013-2019.

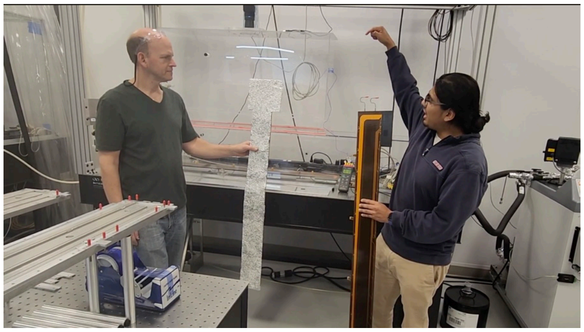


ATLAS stave core production

In order to probe further into unexplored physics territory, scientists seek to collect more collision data per second. The Paul Tipton group accomplishes this through a series of staged upgrades of both the Large Hadron Collider (LHC) at the European Organization for Nuclear Research (CERN) in Switzerland and the ATLAS detector.

In a Wright Lab clean room, a research team led by Tipton is fabricating essential components of a new particle detector that will track the path of charged particles as they leave the collision point of the LHC. Tipton's team, part of the ATLAS collaboration, is working on a schedule such that the new particle tracker will be installed at CERN in 2026.

The Tipton group has been conducting research and development and prototyping the construction of state-of-the-art low-mass structures to hold sensors (i.e., particle detectors) that will track particles as they leave the interaction point. The structures, called stave cores, are the basic building block of the new tracking detector for ATLAS. The stave cores precisely locate the sensors, while also providing cooling and electrical connections into and out of the interaction region.

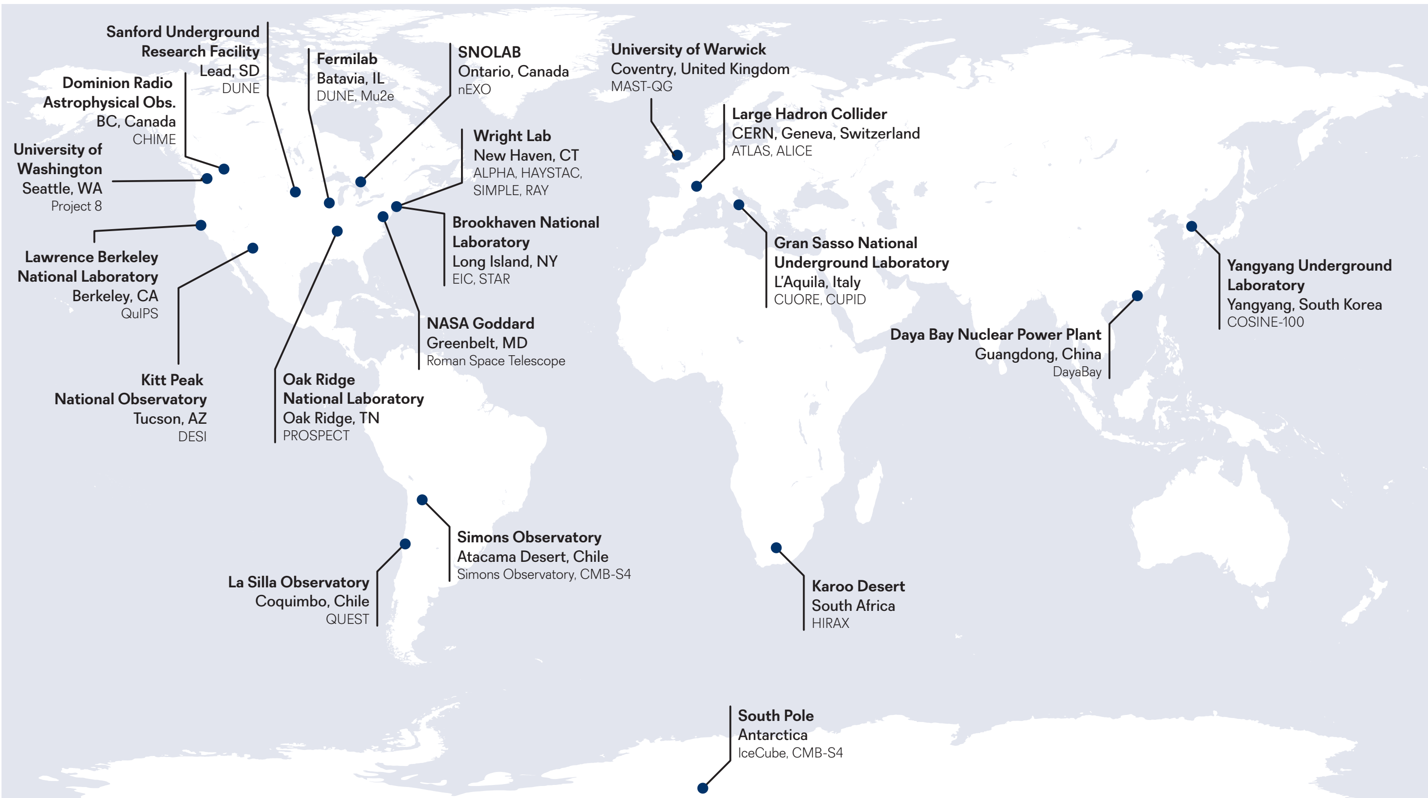


The team will fabricate approximately 225 stave cores, then ship them to Brookhaven National Laboratory (BNL) in New York, where the sensors will be mounted on them, before their journey on to CERN, where they will be installed in the upgraded ATLAS detector.

Collaborations

Wright Lab's research program and on-site facilities foster cross-disciplinary research collaborations at Yale and worldwide in nuclear, particle, and astrophysics; quantum science; and instrumentation development.

Research worldwide



Campus collaborations

- **Yale Center for Astronomy and Astrophysics (YCAA)** - working towards understanding dark matter in the Universe through scientific investigations.
- **Yale Center for Research Computing (YCRC)** - developing novel solutions to the research computing challenges in nuclear, particle, and astrophysics.
- **Yale Quantum Institute (YQI)** - jointly developing quantum sensors and techniques.
- Wright Lab also has **strong interdisciplinary partnerships** with the Institute for the Preservation of Cultural Heritage (IPCH), the Yale Center for Collaborative Arts and Media (CCAM), the Yale Peabody Museum of Natural History, and Yale Pathways to Science.

National laboratory partners

- Brookhaven National Laboratory, New York
- CERN, Switzerland
- Fermilab, Illinois
- Gran Sasso National Laboratory, Italy
- Oak Ridge National Laboratory, Tennessee