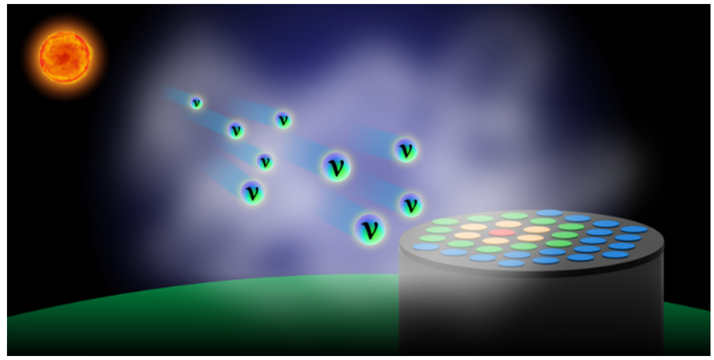
Highlights of the Year

***Physics Magazine* Editors pick their favorite stories from 2024.**

The past year abounded in news from a wide range of scales—from the mechanical detection of single-particle decays in a microscopic bead up to the discovery of surprisingly mature galaxies in the early Universe, with lawn sprinklers, wearable glucose monitors, and car batteries in between. Significant progress was made in inertial confinement fusion, practical quantum networks, and the quest to build a superaccurate clock based on nuclear transitions. This year also marked the point when searches for dark matter became sensitive enough to detect a potentially bedeviling background: neutrinos streaming from the Sun.



Credit: APS/Alan Stonebraker

Wishing you all a splendid 2025!

—The Editors

Toward a Thorium Nuclear Clock

Researchers this year removed a significant obstacle in the way of creating a nuclear clock. The ultranarrow transitions of such a clock would be impervious to distortions by external fields—which should lead to a tenfold improvement of accuracy compared to today's best atomic clocks (see **Viewpoint: Shedding Light on the Thorium-229 Nuclear Clock Isomer**). The team measured the transition energy and wavelength of the only atomic nucleus believed to be accessible via laser manipulation and precision spectroscopy: an excited state of the isotope thorium-229. The measurement entailed using laser light to excite the isomer from the nuclear ground state, which is the crucial step required for controlled operation of a nuclear clock.

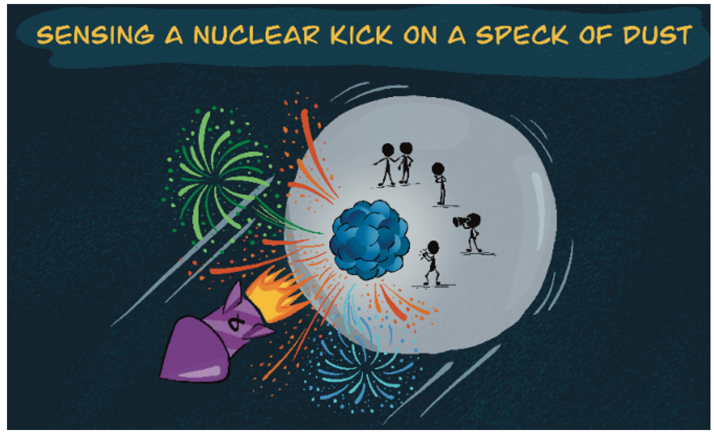
Credit: APS/Alan Stonebraker

Sample-Free Sensing of Blood Sugar

Current methods of determining the level of glucose in a person's bloodstream rely on measuring it either directly from a blood sample or indirectly via sweat, tears, or other bodily fluid. *Physics Magazine*'s most read news story of 2024 described an idea for a new wearable technology that can measure blood glucose continuously and without the need for a sample (see **Synopsis: One Ring to Measure Blood-Glucose Level**). The proposed ring-shaped device, reported in *Physical Review Applied*, emits a radio-frequency signal into the wearer's finger. The spectrum of the radiation scattered within the finger depends on the level of glucose in the wearer's blood. Numerical simulations confirmed that amplifiers and sensors on the ring's inner surface could measure the spectral changes and correlate them with glucose level.

Neutrino Fog Rolling into Sight

After years of null results, dark matter searches might finally have a real signal to contend with. Alas, the signal doesn't come from dark matter particles but from a stream of neutrinos produced by nuclear reactions in the Sun (see **Research News: First Glimpses of the Neutrino Fog**). In 2024, the PandaX and XENON collaborations independently reported that their detectors have likely started to see this "neutrino fog." Whereas in the long run the neutrino fog could pose a threat to dark matter searches, researchers agree that its impact won't be felt until next-generation experiments kick off in a decade or so. What's more, dark matter experiments could be turned into multipurpose detectors for probing various aspects of neutrino physics.



Credit: APS/**Laura Canil**

Fusion-Energy Breakeven Confirmed

The National Ignition Facility's 2022 demonstration of a nuclear-fusion reaction that produces more energy than it consumes has officially been verified. In February, five peer-reviewed reports describing this milestone in laser-induced fusion were published (see **Viewpoint: Nuclear-Fusion Reaction Beats Breakeven**). Updates to the fuel capsule, laser configuration, and fuel composition all helped to enable the increased energy output. Analyzing the fusion-reaction regime of experiments performed in March and August 2021, the NIF researchers found that a fourfold increase in the volume of the reacting plasma inside the capsule corresponded to a 20-fold increase in the fusion-energy output. Although the reported fusion-energy yield was less than the electrical energy required to operate the system lasers, improvements are in the works to upgrade both reaction and laser efficiency.

Nuclear Decay Measured Mechanically

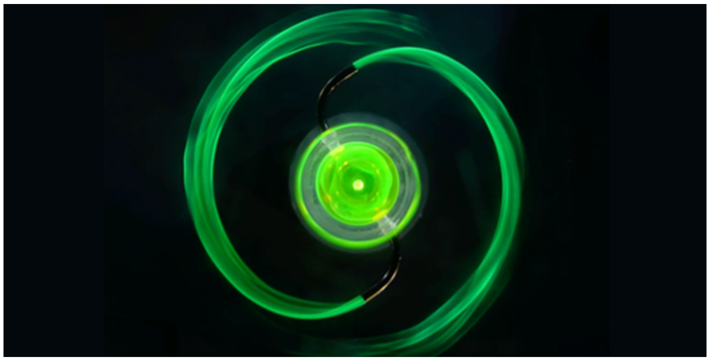
In July, researchers detected the recoil imparted by the emission of a single alpha particle (see **Viewpoint: Nuclear Decay Detected in the Recoil of a Levitating Bead** and **Special Feature: Sensing a Nuclear Kick on a Speck of Dust**). The team embedded a few dozen atoms of radioactive lead-212 in the surface of a microscopic silica bead, which they levitated in an optical trap. Changes in the bead's net charge due to alpha and beta decay showed up in the way the bead responded to an oscillating electric field. Those alpha decays also caused minute "kicks"—changes in the bead's momentum—which were measurable by observing the way the bead scattered light.

An Alternative to Traditional Magnets

As far as types of magnets go, there is nothing new under the Sun. At least that was the prevailing opinion until altermagnets hit the scene. Proposed by several groups over the past few years, altermagnets are somewhere between ferromagnets and antiferromagnets (see **Viewpoint: Altermagnetism Then and Now**). These potentially useful materials lack net magnetization (like antiferromagnets) but have magnetically sensitive energy levels (like ferromagnets). Experimental evidence for altermagnets started to trickle in this year. One study showed that the electronic bands of manganese telluride can split in two under a magnetic field—a predicted property of altermagnets (see **Synopsis: Experimental Evidence for a New Type of Magnetism**).

New York Hosts Ground-Breaking Photon Demonstration

In New York City, it's not just the people who "ride in a hole in the ground"—it's also the photons, sent through fiberoptic internet cables. In a step toward future networks connecting quantum processors, researchers demonstrated sending 20,000 quantum mechanically entangled photons per second continuously for two weeks through a 34-km fiber-optic loop under the city (see **Focus: Entangled Photons Maintained under New York Streets**). Photon entanglement is fragile, particularly in the unpredictable and fluctuating conditions of underground cables. But the team used classical photons to continuously monitor the entangled photons' final polarizations and then used that information to compensate for



Credit: K. Wang *et al.* PRL 132, 044003 (2024)

the disturbances.

Tackling an Early-Universe Puzzle

With its ability to peer farther into the Universe than any other galaxy-imaging telescope, the JWST revealed an expectedly large number of bright, early-Universe galaxies (see **News Feature: JWST Sees More Galaxies than Expected**). The finding was initially interpreted as a challenge to the existing paradigm of cosmology—the ΛCDM model. But further scrutiny suggested that the problem may instead lie with astrophysical models for galaxy and star evolution. Astrophysicists have put forward possible explanations for this puzzle, most of which involve the idea that stars and galaxies in the early Universe behaved differently from those in today's Universe. Further measurements by the JWST may solve the puzzle within the next year.

Settling a Sprinkler Controversy

A lawn sprinkler spins around in a circle, driven by outgoing jets of water. But does it spin in reverse when water is sucked in through the nozzles? The question—popularized by the physicist Richard Feynman—eluded a definitive answer for decades until an experiment this year put the issue to bed (see **Focus: Feynman's Reversed Sprinkler Puzzle Solved**). To overcome frictional effects that confounded previous experiments, the researchers built a floating sprinkler that could either spray out or suck in water. The sucking did result in a reversed rotation, which was slower and less continuous than the normal forward spinning. Meanwhile, a sprinkler analogy might be helpful in understanding the "many-worlds" interpretation of quantum mechanics (see **Viewpoint: Can Classical Worlds Emerge from Parallel Quantum Universes?**)

Sodium Batteries Worth Their Salt

Lithium-ion batteries have powered revolutions in personal electronics and electric vehicles, but they have environmental costs, including those associated with mining and shipping a relatively rare element. Sodium, a chemical cousin of lithium, is 1000 times more abundant and has recently seen a burst of battery research and development (see **News Feature: Sodium as a Green Substitute for Lithium in Batteries**). Companies have even begun commercializing sodium-ion batteries for power tools and small electric cars. Sodium batteries can operate at high powers and at low temperatures, although they don't pack as much energy per kilogram as lithium batteries do. Researchers expect sodium to be competitive with lithium, at least for certain applications, within a matter of years.