

Muon detectors for the people!

The specialized devices are democratizing access to cosmic-ray experiments.

By **Jenessa Duncombe**

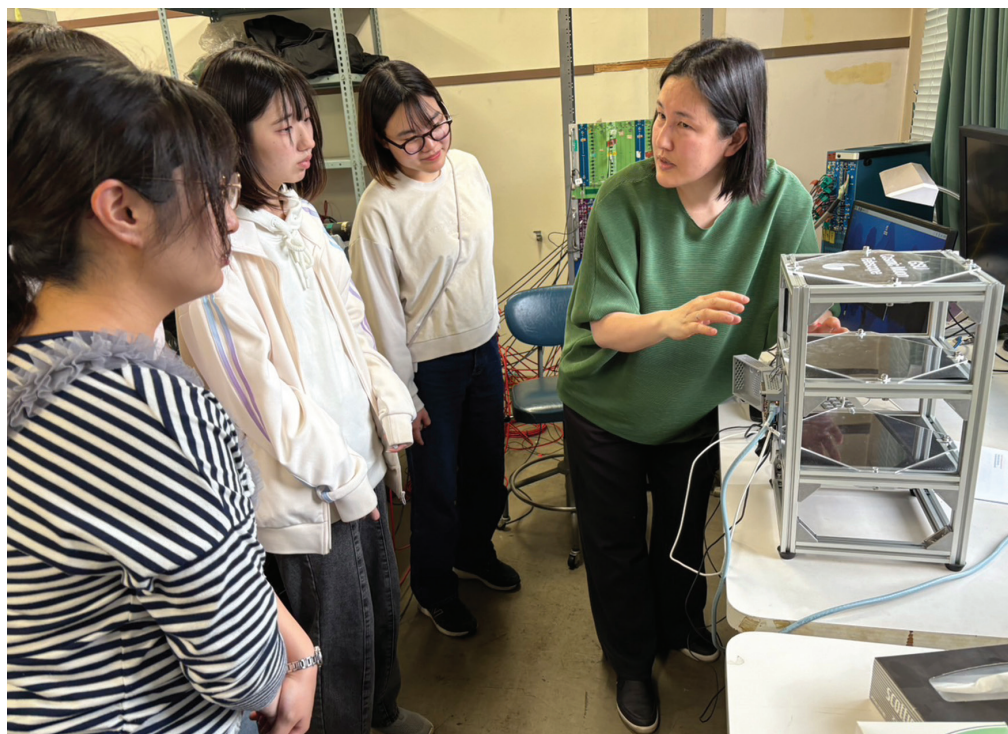
Handheld and tabletop muon detectors have proliferated in high school and college classrooms in recent decades. The instruments are safe, low cost, and durable, and they open possibilities for exploration in physics, space-weather studies, and atmospheric science. Several programs, shown in the table on page 20, have taken different approaches to supplying muon detectors to students and researchers. Together, the initiatives have resulted in the deployment of thousands of muon detectors worldwide, according to estimates by program organizers.

When a cosmic-ray proton or nucleus that comes from the Milky Way, another galaxy, or the Sun and travels near the speed of light collides with Earth's atmosphere, the clash produces a shower of particles. Those particles can decay into muons, subatomic particles that have the same charge as electrons but are 200 times as massive. Muons at rest have a lifetime of just a few microseconds, but if cosmic-ray muons are

moving fast enough, relativistic time dilation will allow them to survive long enough to reach Earth's surface. About two to three muons per second pass through an outstretched hand of someone on Earth.

Showers of muons provide ample potential for experiments with small-scale detectors. For example, people interested in physics and astrophysics can deploy muon detectors to study special relativity, radioactive decay, or gamma rays. Those interested in space or planetary weather can measure hurricanes or the onslaught of coronal mass ejections. Those scrutinizing human civilizations can study muons passing through ancient ruins. (See *PT*'s 2004 story "Muons may unlock secrets of Teotihuacan.")

The primary goals of two muon-detector programs, CosmicWatch and QuarkNet, are outreach and education. Spencer Axani, a University of Delaware physics professor who founded CosmicWatch while a graduate student at MIT, says he receives frequent emails from high school and undergraduate students who



◀ Physics professor Shimomura Maya at Nara Women's University in Japan shows students a tabletop muon detector from the gLOWCOST program in April 2025. (Photo courtesy of Xiaochun He.)

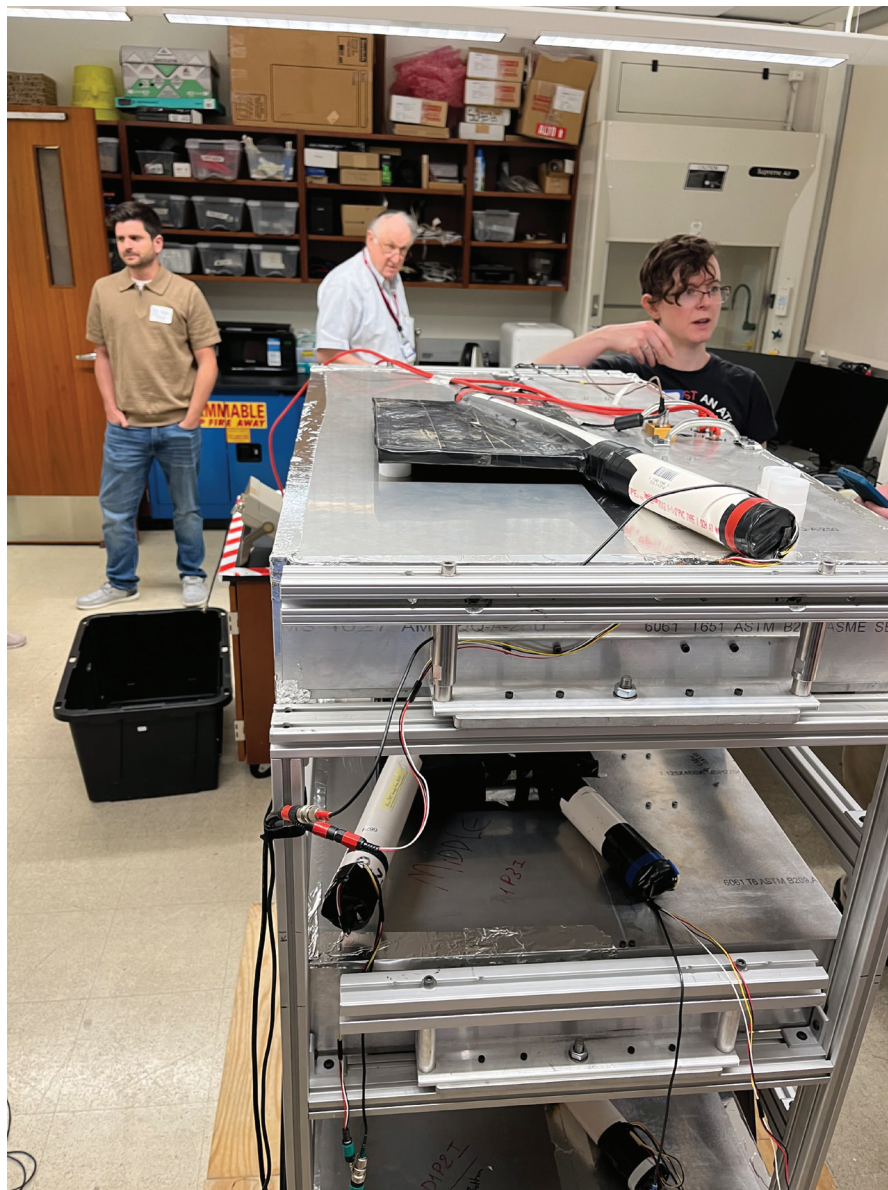
Program	QuarkNet	CosmicWatch	gLOWCOST
Founded	1998	2017	2023
Organizers	Fermilab and the University of Notre Dame	University of Delaware and MIT	Georgia State University
Muon detector	Tabletop; provided either disassembled or fully assembled	Handheld; provided either disassembled or fully assembled	Tabletop; provided fully assembled
Primary users	High school classrooms	Individuals; high school and college classrooms	Research laboratories; middle school, high school, and college classrooms
Data sharing	Online data portal	Under development	Daily plots; data available on request
Funders	DOE, NSF	NSF, MIT, SensL, Wisconsin IceCube Particle Astrophysics Center, National Centre For Nuclear Research (Poland)	Georgia State University, DOE, NSF
Distribution	Several hundred	3000–5000	28
Cost	Free for participating teachers; valued at \$3000–\$4000	Estimated cost of purchasing DIY electronics, \$100; fully assembled detector sold for \$299 or as a pair for \$499	Free for participating groups; valued at approximately \$700

are designing experiments using CosmicWatch detectors for their applications for college and graduate school. Some undergraduate physics courses now distribute CosmicWatch detectors to students for coursework. (See Axani’s 2017 *PT* article “An easy-to-build desktop muon detector.”)

QuarkNet pairs particle physicists with high school teachers through 50 regional teaching hubs in the US. The program distributes muon detectors and instructs teachers on how to teach with them. Some 400–500 teachers per year are involved in the program, says Mark Adams, an emeritus physics professor at the University of Illinois Chicago and a QuarkNet master

teacher. Dozens of participating high schools have banded together over the years to monitor storms, coronal mass ejections, and eclipses with QuarkNet detectors. Teachers often hang on to their detectors until retirement, says Adams, who helps refurbish them and sends them to new teachers.

The newest of the programs is gLOWCOST (global low-cost observation of the dynamic changes in the space weather and terrestrial weather). It distributes fully assembled and calibrated tabletop muon detectors to research groups worldwide. Xiaochun He, a physics professor at Georgia State University and gLOWCOST’s founder, believes that if the project is



◀ QuarkNet muon detectors stacked in a cosmic-ray experiment for a teacher training. For this activity, the paddle-like detectors are measuring the muon rate as a function of zenith angle. (Photo by Mark Adams.)

successful, it will not only provide outreach opportunities for middle and high school students but also create a global cosmic-ray muon-flux monitoring network for space and terrestrial weather. He says his goal is to deliver detectors to researchers in more than 100 countries in the next five years.

These outreach activities can inform research, says Janet Conrad, an MIT physics professor and CosmicWatch cofounder. CosmicWatch's prototype inspired the "grandchildren" of cosmic-ray detectors installed in the recent upgrade to the IceCube Neutrino Observatory, says Conrad. (See *PT*'s 2026 news story "IceCube expands neutrino search to spot fainter signals.")

Physics professor David Ruffolo at Mahidol University in Thailand has advised teachers using CosmicWatch detectors in high school classrooms in the country. He is enthusiastic about the benefits for students, though he cautions teachers from expecting publishable results from individual, small muon detectors. Time-dependent atmospheric effects and the influence of the local environment on cosmic-ray muon flux at ground level makes achieving statistically significant results difficult. "For a small muon detector," he says, "it is better to stress the student experience, and not to place expectations on scientific output."

PT