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Stony Brook physicist hopes to create underground lab

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EMPIRE, Colo. -- Looking out from this former boomtown, a heady sense of expectation still seems to fill the valley where New York City prospectors arrived with the 19th-century gold rush and pinned their hopes on a settlement named for their distant Empire State.

Looking up into the nearly cloudless blue, a seductive vision of the 21st century also seems within reach, as another New Yorker, Stony Brook University physicist Chang Kee Jung, dreams of unlocking the mysteries within a stream of tiny particles raining down from the cosmos.

Even now, these bits of matter ejected from the sun or a distant supernova -- even relics of long-dead stars -- are everywhere around us. Even now, they are sweeping past Empire's own Park Avenue, past the gates of a working mine to the west of town and down through a mile of solid granite.

In the not-so-distant future, perhaps, these ghostly specks will filter through the mine and reveal themselves deep underground, one by one, in a water-filled detector the size of a 16-story apartment complex. And then, just maybe, the tiny enigmas known as neutrinos will tell scientists some of the universe's oldest secrets.

"This is one of the juiciest stories in particle physics history," says Jung. And as one of the chief protagonists, he is smack-dab in the middle of it.

One step away

After a nationwide search, Jung has helped position Colorado's Henderson mine as one of two front-runners for a National Science Foundation project worth up to $500 million, including infrastructure and experiments.

If Jung and his collaborators prevail, they will win the right to build the country's first deep underground laboratory, within the Arapaho National Forest less than an hour west of Denver -- and Stony Brook University would take the lead in managing a scientific space that is already whispering of the wonders to come.

For physicists, the torrent of subatomic specks constantly bombarding our planet contains vital clues to some of the biggest unanswered questions: What is the universe made of? How has it evolved? And what, exactly, is the mysterious substance known as dark matter?

If only those particles harboring the best information could be coaxed away from the downpour obscuring the view.

Fortunately, the particles known as neutrinos -- formed chiefly through nuclear reactions -- possess fascinating histories and a superhero-like ability to pass through nearly any surface unimpeded. To access the information stored within them and similar specks but filter out less penetrating cosmic rays, scientists have turned to detectors positioned in the ocean depths, beneath Arctic ice or deep underground.

With the majority of particles turned away, the torrent becomes a more manageable trickle. And with their identities revealed, the remaining bits of matter may divulge their cosmic origins and disclose how the universe gave rise to suns and supernovas, black holes and dark matter.

Awestruck by the possibilities after his first trip through the mine, Jung knew he had found something extraordinary. Somewhere beneath the labyrinth of wide tunnels carved into granite, he decided, physicists could open a new window to the cosmos -- and maybe build the world's largest neutrino detector to expose the otherworldly particles.

"When I came out, my impression was that this is like the first time you meet Angelina Jolie," he says. "My jaw dropped."

This spring, the National Science Foundation is widely expected to back either the Henderson Underground Science and Engineering Project or a competing plan for the shuttered Homestake gold mine in the Black Hills of South Dakota.

Either way, scientists are cheering the virtual certainty that the United States will finally have a deep underground laboratory of its own -- a boon to physicists, microbiologists and geochemists alike.

Seeking evasive clues

In the early '70s, Brookhaven National Laboratory physicist Raymond Davis used a 100,000-gallon tank full of dry cleaning solvent to capture neutrinos nearly one mile beneath the surface of Homestake. His famed experiments proved the sun produces the ethereal particles -- producing sunshine as a byproduct -- and earned him a share of the 2002 Nobel Prize.

A decade after Davis ventured into the mine, a group of physicists floated the idea of a permanent lab for similar experiments requiring an effective particle shield. Italy had recently carved out such a space in a mountainside and Japan was doing likewise in an old zinc mine.

The U.S. proposal failed to gain wider support, however, limiting experiments to modest sites like Homestake and a decommissioned iron mine in northern Minnesota.

With the announcement in 2000 that Homestake's owner planned to close the mine, scientists revived their plans for a research space. Residents and officials in Empire and nearby towns proposed the same thing after hearing that the Henderson mine could dig itself out of business within two decades.

Jung soon gained the enthusiastic support of Climax Molybdenum, the mine's owner, and he assembled a team that now includes Colorado's top research institutions and more than 160 collaborators. A lengthy process has since left Homestake and Henderson as the favorites in a winner-takes-all sweepstakes among eight contenders.

Treasure of the mountains

Far below the Colorado mine's scenic backdrop of evergreen-covered Harrison Mountain and its more exposed fraternal twin, Red Mountain, researchers have already begun collecting scientific treasures.

Microbiologists have discovered at least three new bacterial groups in mine drainage holes, part of the quest to define the limits of life on Earth and beyond. Geologists are planning for an unprecedented vantage from which to study seismic waves and the mine's rich deposits of molybdenum, a silvery ore used in products ranging from lubricants to light bulbs.

And physicists such as Jung are hoping that a suite of deep-seated detectors might even validate a sweeping theory that Albert Einstein once puzzled over in his effort to unify nature's fundamental forces.

It's a tall order, perhaps, and all the more incongruous when a manager of Climax Molybdenum points out the unassuming chamber where it could all begin. Should the project get the go-ahead, the company would continue operating while likely giving researchers a machine shop more than three-fourths of a mile underground, where dusty front-end loaders sit scoop to scoop and "Uncle John's Band" by the Grateful Dead fills the void on an early fall morning.

The upper campus fashioned within the maintenance area now filled with heavy mine machinery could house the experiments given highest priority, while others would await the excavation of more tunnels, zigzagging ramps and deeper caverns.

From a deep exploration station 1.4 miles beneath Harrison Mountain's peak, scientists could drill an extra one to two miles down to search for new frontiers of underground life.

Shrinking toward the infinite

The frontiers of particle physics, meanwhile, have unearthed ever-smaller bits of matter: first the atom, then the protons and neutrons in its nucleus and the electrons orbiting the core like tiny satellites. And then the strange and truly tiny building blocks dubbed quarks.

Scientists now suspect an atom's proton particles might eventually decay, a phenomenon that could suggest how fundamental forces such as gravity and electromagnetism are organized -- something even Einstein couldn't fathom. Recent calculations, however, also suggest that the average life span of a proton could dwarf the age of the known universe.

Jung likens the seemingly impossible task of detecting a decaying proton with playing the lottery: "If you buy one ticket," he says, "then there's an insignificant probability that you'll win, but if you buy all the tickets, then you win."

The jackpot could eventually come with the mammoth Underground Nucleon Decay and Neutrino Observatory, built to unmask neutrinos and decaying protons alike. The detector isn't even in the initial proposal; the price tag for the 16-story structure could top $500 million and would require an unprecedented excavation.

"It would be the largest underground civil-use structure ever built," says Mark Kuchta, a mining engineer at the Colorado School of Mines in Golden who has accompanied Jung on his visit.

Even so, the collaborators believe the case for doing so is compelling. The mine's infrastructure is up to the task, they believe, and the construction of other facilities during the project's first phase could pave the way for the groundbreaking neutrino observatory and an influx of the scientific world's brightest minds.

Out of the shadows

With any luck, other detectors could unmask the identity of a third cosmic phantom.

Dark matter, thought to account for a quarter of the universe, has so far defied all efforts to categorize it.

Some suspect the stuff is made of tiny relic particles created during the Big Bang, the primeval explosion that marked the formation of the universe. Others think dark matter is synonymous with light-sucking black holes or the dim stars known as brown dwarfs. Some clarification of where all the universe's missing mass has been stored could come with a detector designed to pick up signals of the possible Big Bang-era particles.

Everything, of course, depends on winning the competition and then carving sizeable rooms from solid granite. Exploratory cores have been drilled to two of the possible expanses to make sure the granite is strong and lacks valuable molybdenum ore. Fortunately, neither core revealed any "show-stoppers," Kuchta says.

A half-hour to the east, environmental microbiologist John Spear has assembled another group of scientists hoping to explore the mine's underground expanses.

Spear's colleagues, gathered in his lab at the mining school, explain how an analysis of water pouring through drainage holes in the mine's lower reaches has uncovered a variety of fluids rich in dissolved metals and carbon dioxide.

"You can step meters away and depending upon the rock type, the chemistry changes," says Alexis Templeton, a geochemist at the University of Colorado at Boulder.

Full of metals like iron and manganese, the chemical concoction gushing from the bore holes is actually closer to what would be expected near a deep-sea hydrothermal vent than anything found on the surface, she says, and the walls are covered with minerals that have precipitated out of solution where the water flows through the rock.

With its abundant carbon dioxide, she says, "the water is literally fizzing."

Just beyond their door

Beyond the unique chemistry, scientists are asking what life it can support and where that life originated. So far, abundant microbes have been found where the water pours from the bore holes.

More notably, Spear and his colleagues have found three new groups of bacteria in holes they had plugged and deprived of all oxygen.

"It's kind of like walking out your front door," Spear says, "and discovering plants for the first time."

Life deep underground, though, is likely to differ from anything on the surface -- a point not lost on astrobiologists who believe any life on Mars would be found in the planet's subsurface.

On Earth, the realm of the living has been extended by the discovery of heat-loving microbes in deep South African gold mines and of pressure-tolerant bacterial mats beneath the ocean floor.

Microbes within the Henderson mine's granite depths would likewise grow very slowly, trapped within the hot, high-density and arid rock.

Spear retrieves a pale pink section of that rock, extracted from one core drilled through the mine's depths. Later, he confirms that a DNA analysis has detected a microbial presence.

Jung, focusing on the particle physics possibilities, laughs at how little he had thought about testing the granite cores for signs of life. That anything could bloom within the most barren-seeming expanse may well be one of the mine's biggest wonders yet.

With their fingers crossed, Jung and his collaborators keenly hope it will not be the last.