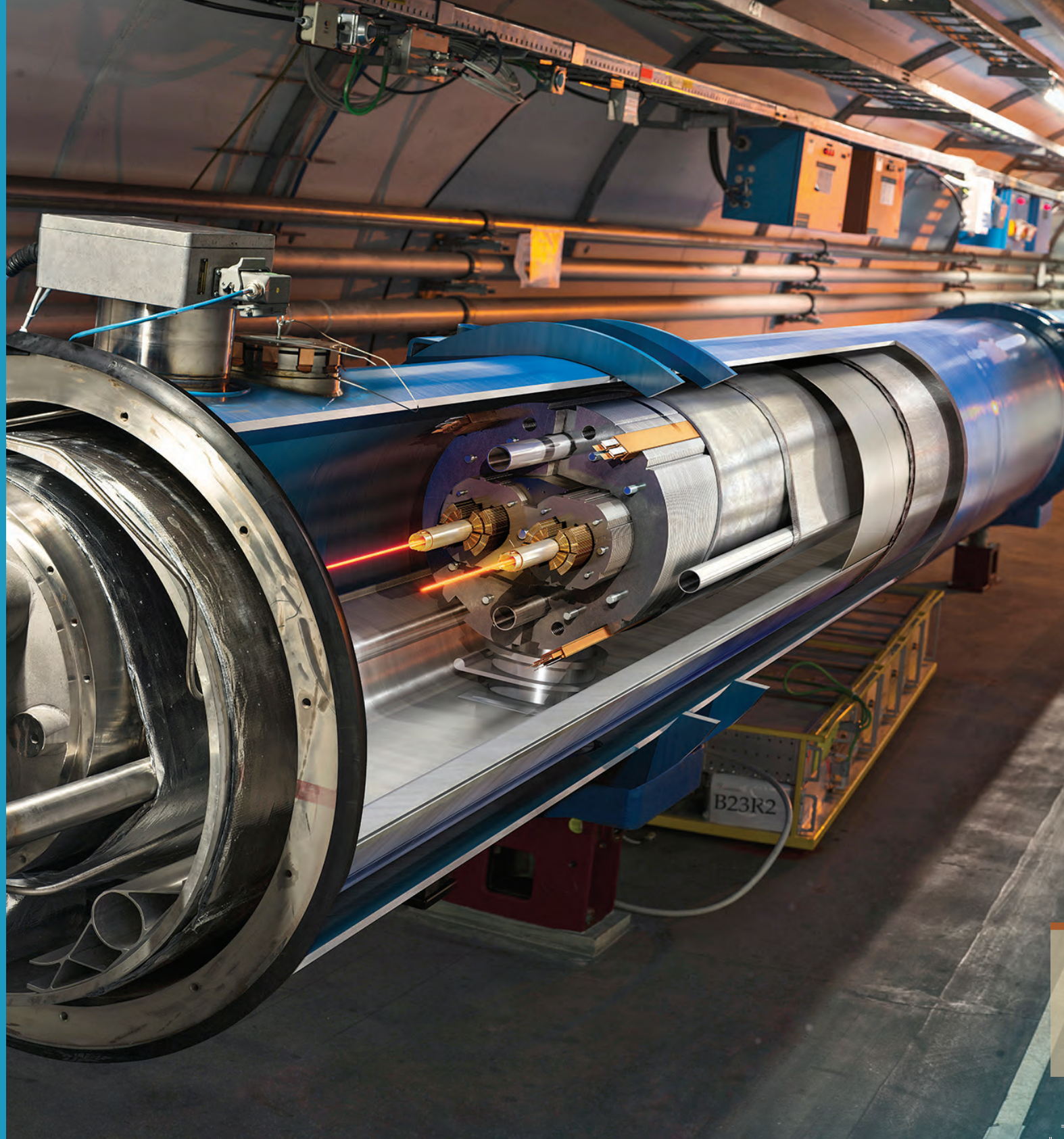


SMASHING ATOMS

UNL RESEARCHERS TAKE KEY ROLE IN GLOBAL EFFORT





By Gillian Klucas, '91

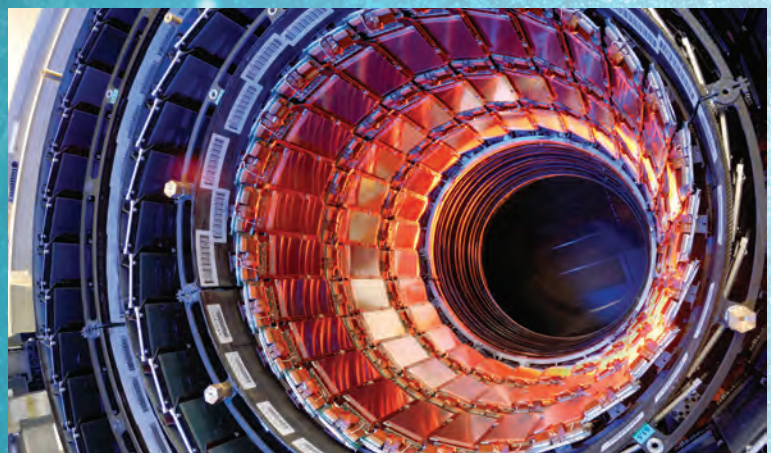
As UNL physicist Aaron Dominguez squeezed into the spartan conference room, he'd never seen anything like it. Scientists were packed into every video-networked room, spilling into hallways at the European Organization for Nuclear Research, known as CERN, outside Geneva, Switzerland. The heady excitement felt more like a rock concert than a scientific symposium.

Around the world, thousands of particle physicists were tuning in to find out if they had, collectively, found it: the Higgs boson, the subatomic particle at the heart of all matter in the universe. The search for the so-called "God particle" was the largest global scientific collaboration ever attempted. It was culminating in this moment: Had they unlocked a key mystery of the universe or was the pursuit hopeless?

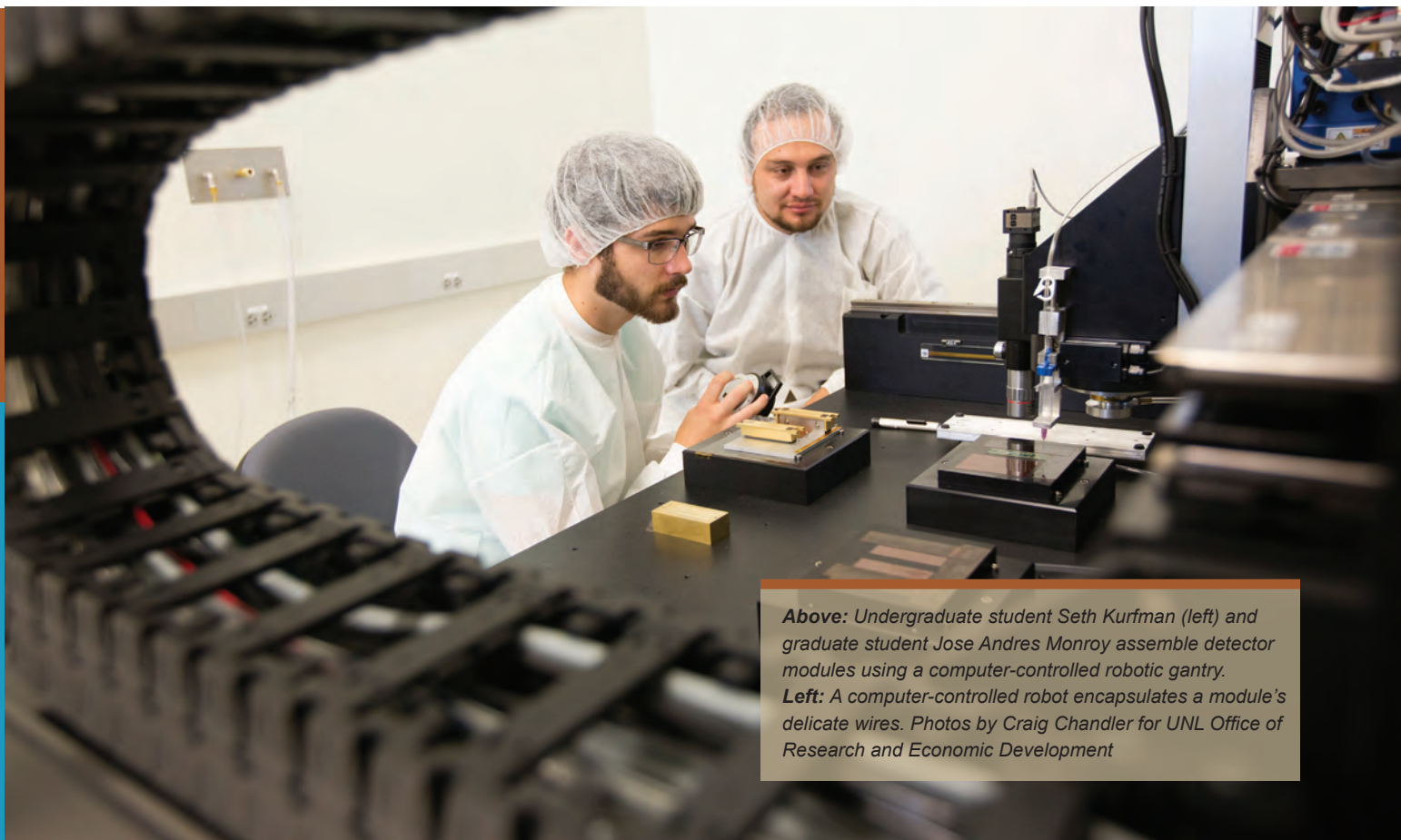
Dominguez and his colleagues in UNL's particle physics team had played a significant part in that pursuit. Thunderous cheers greeted the successful results announced that summer day in 2012. Finding the Higgs boson – one of the most important discoveries ever in the field – heralded a new era of fundamental physics.

This spring, CERN again revved up the Large Hadron Collider, or LHC, the world's largest supercollider buried deep below the countryside on the French-Swiss border. The collider began smashing atoms together – this time with twice the energy. Scientists hope the resulting subatomic wreckage will reveal, for a blink of time, additional clues about the nature of the universe.

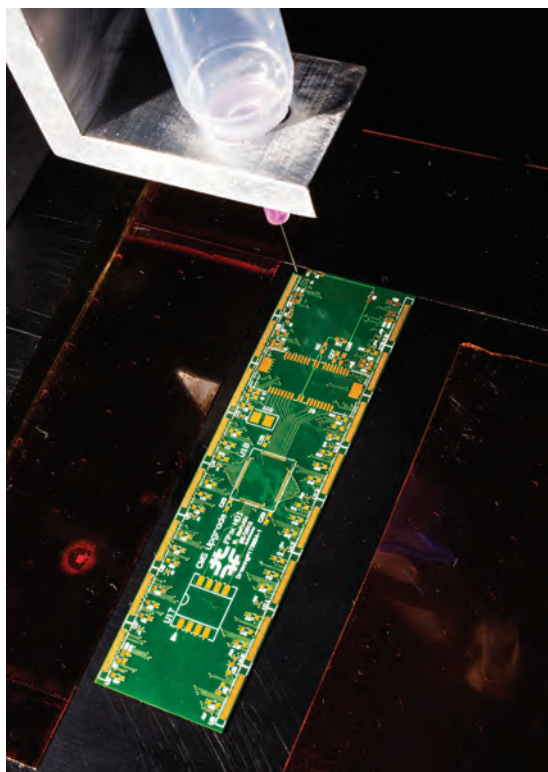
As the latest LHC experiments begin, UNL's particle physicists continue their leadership roles in two key aspects of this international collaboration. One team pilots the U.S. efforts to provide vital components for one of the LHC's two particle detectors. The other team contributes to the worldwide computing grid that processes and stores the unprecedented volume of data this massive research project generates.



Large Photo Above: A 3-D composite illustration shows a portion of the Large Hadron Collider tunnel. Right: First half of the pixel tracker barrel of the Compact Muon Solenoid detector. UNL researchers were part of the team that built the CMS detector in 2009 and are now leading U.S. efforts to improve the detector. Photo credit: CERN



Above: Undergraduate student Seth Kurfman (left) and graduate student Jose Andres Monroy assemble detector modules using a computer-controlled robotic gantry. Left: A computer-controlled robot encapsulates a module's delicate wires. Photos by Craig Chandler for UNL Office of Research and Economic Development



DETECTING PARTICLES

Building components for an instrument more than four stories tall, just as wide and weighing 28 million pounds takes place in a surprisingly small space on UNL's campus, a room about the size of a large walk-in closet. Inside, a tabletop robotic arm and several specialized microscopes conduct minuscule maneuvers.

"You don't need a big space to do tiny little things," explained Frank Meier Aeschbacher, a postdoctoral fellow who oversees assembling and testing pixel detector modules. Within two years, the modules will be doing their job inside the not-so-compact Compact Muon Solenoid particle detector, or CMS. Each module resembles an electronic circuit board that could fit inside a pack of gum, but these circuits must withstand tremendous radiation.

CMS is one of two particle detectors spaced around the 17-mile-long LHC supercollider ring. Each was designed differently, but their goals are similar: to capture and measure the properties of the products that result when two beams of protons circling in opposite directions at near the speed of light crash head-on. CMS takes 40 million snapshots of the events every second, captured in part by pixel detector modules. The U.S. team is responsible for building 1,000 modules, half of which will come from Nebraska.

These intricate, custom-made components produce 90 percent of the results from the CMS experiment, said Aeschbacher, who was lured from his native Switzerland to work for Dominguez on the project.

Thousands of scientists at more than 180 institutes in 42 countries are involved in the CMS project. They will analyze the data to look for new fundamental particles and study their characteristics. They hope the insights will shed light on such mind-numbing theories as how the universe was formed, what's up with dark matter, and the possibility that additional universes exist.

UNL was part of the multi-institutional collaboration that built the original CMS detector in 2009. The LHC shut down for upgrades two years ago. Now, with \$11.5 million funding from the National Science Foundation, Dominguez is leading researchers

from several U.S. universities to improve CMS's capabilities.

"We're increasing the intensity of the accelerators. Our detectors need to be able to handle the increase in data or it becomes self-defeating," he said. "This will be the most precise pixel-tracking detector ever built."

Dominguez's prominent leadership role has boosted the university's contribution – and reputation – in one of the world's biggest physics experiments, said Dan Claes, a member of UNL's particle physics group and chair of the physics and astronomy department. Dominguez's hard work and amiable nature helped him quickly climb the leadership ranks, and he now oversees the contributions of numerous U.S. teams on the project.

"It raises the prominence of Aaron; it raises the prominence of our group; and it raises the prominence of the University of Nebraska-Lincoln," Claes said.

For Dominguez, who grew up relishing science in Albuquerque, New Mexico, studying the universe at its most fundamental level is "the best job in the world." He joined the hunt for the Higgs particle, which had occupied physicists since it was first proposed in 1964, as an undergraduate student at the California Institute of Technology in the early 1990s.

"Finding the Higgs boson required, literally, the cooperation of thousands of physicists around the world," Dominguez said. "That we finally pulled it off is really quite satisfying in ways that are hard to express."

The Higgs particle was the last missing piece predicted by the Standard Model, a theoretical framework that explains the fundamental structure of matter in the universe. The model describes how forces acting at the subatomic level govern the interactions of elementary particles that make up all matter.

Though often called the "theory of everything," the Standard Model is far from complete. It doesn't address important phenomena such as gravity, the dark matter that makes up most of the universe, or the even more mysterious dark energy.

"There's still a lot we don't know," said Dominguez. "We have a great opportunity to look for evidence of other new particles and to open up the next generation of models into how the universe works."

COMPUTING POWER

In 2004, recently hired particle physicist Ken Bloom listened as Vice Chancellor for Research Prem Paul urged UNL's new faculty to "think big."

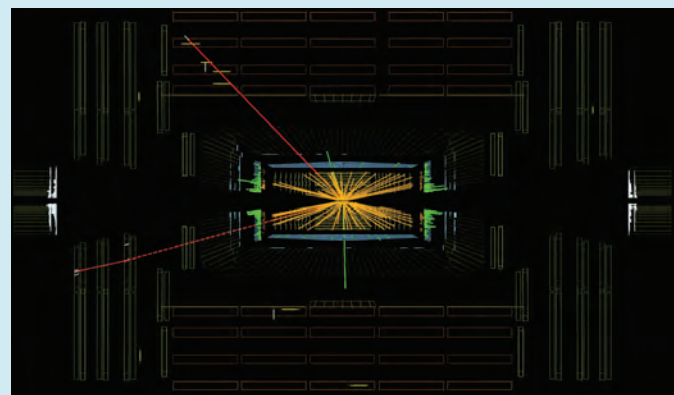
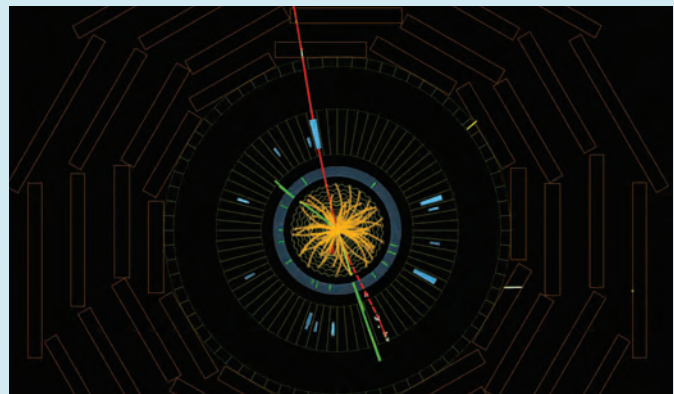
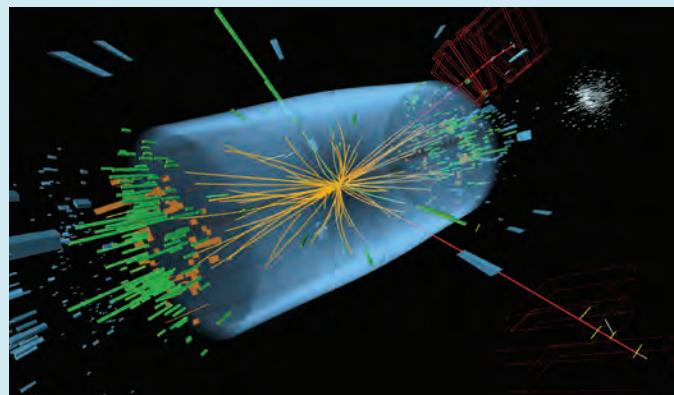
Afterward, Bloom jumped up to tell Paul that he and fellow newcomer Dominguez had a big idea, and they would fulfill it in their first year.

"I didn't know how to interpret him," Paul recalled with a laugh. "It's exciting that he's trying to do exactly what I'm asking him, but then I thought, 'Is he brash?' I think my reaction was probably not what he was looking for."

Supercollider collisions generate such enormous quantities of data – the equivalent of about 7 million DVDs worth each year – that the computing power to store, move, process and analyze it requires a global network of computer

THE GOD PARTICLE

SHOWN BELOW ARE IMAGES OF PROTONS COLLIDE IN THE CMS DETECTOR. THIS IMAGE PROVIDED EVIDENCE OF THE HIGGS BOSON, THE SUBATOMIC PARTICLE AT THE HEART OF ALL MATTER IN THE UNIVERSE. THE SEARCH FOR THE SO-CALLED "GOD PARTICLE" WAS THE LARGEST GLOBAL SCIENTIFIC COLLABORATION EVER ATTEMPTED. IMAGES PROVIDED BY CERN.



systems pulling together.

When CERN began setting up its computing grid in the early 2000s, UNL was a dubious choice to participate. But that's exactly what Bloom and Dominguez hoped to achieve: to put the university on this global computing grid, responsible for storing vast amounts of data and making it accessible to physicists worldwide.

It would be a big, if unlikely, coup. The university's 600-megabits per second bandwidth capacity seemed meager compared with other universities already breaking into gigabit territory.

"We were two young professors," Bloom recalled. "What did we know about what was possible or not?"

They enlisted David Swanson, head of what is now the university's Holland Computing Center. Swanson saw it as an exciting opportunity, but to impress CERN officials, the team would need to convince UNL's administration to invest in upgrading the university's network.

Recognizing the potential benefits, Paul backed the project with a million-dollar investment in fiber optic upgrades. He admits it made him nervous.

"I didn't know what I was getting into," he said. "The good thing is this project really was big, and I'm very proud of our faculty for their leadership, their vision."

Administrative support was critical to UNL's successful 2005 bid to join the worldwide LHC computing grid.

Several upgrades later, Nebraska's 100-gigabit capacity and highly dependable computer networking system is considered one of the world's most reliable "Tier 2" CMS sites, Aeschbacher said. Tier 2 sites store and share the final layer of data used by physicists around the world.

"The performance of our Tier 2 center put Nebraska on the map," Claes said. "Most of the benchmark measures of performance are set by the team at UNL. That was under Ken's supervision. He's inexhaustible in managing and taking care of details in ways that few people are."

Bloom's early success led to an even greater role within CMS when he was quickly chosen to lead all seven CMS Tier 2 sites in the U.S. This year, Bloom accepted an even larger responsibility, managing the entire software and computing

operations program for U.S. CMS. It's a long way from his reign as captain of the physics team at his New Jersey high school. After graduation, Bloom headed west to attend the University of Chicago. Like Dominguez, he began working for a particle physicist as an undergraduate and never looked back.

"We want to be sure that nothing holds anyone in the U.S. back from doing the best science possible," Bloom said of his new responsibilities.

Supercomputing in research – from astronomy to zoology – has advanced considerably in the past decade. UNL's early investment in its computing infrastructure, stimulated by the CMS project, is helping other researchers across the university stay on the cutting edge as well, Swanson said.

A SPECIAL PLACE

Founded in the aftermath of World War II, CERN's goal was to rebuild atomic physics through peaceful international collaboration. That the \$10 billion LHC program continues to receive funding from numerous governments, some of which don't get along, speaks to what it's accomplished and the prospect of more discoveries.

"The next year or two has the potential to be really exciting," Bloom said. "We're very hopeful that we'll see something interesting and unexpected."

UNL's particle physics team, which also includes physicists Greg Snow and Ilya Kravchenko, will be there. Since 2005, the team has won more than \$30 million in grants from NSF and the U.S. Department of Energy to support this research. Its growing reputation brings new research opportunities and draws students, who have the opportunity to train on a significant, international project.

"The CERN laboratory, I think, is one of our greatest achievements of humankind. It's a special place," Dominguez said, speaking of both its ability to unite tremendously diverse talents and perspectives to work toward a common goal and the scale of its scientific achievements.

"It's truly amazing. You go there and you see millions of cables, and every single cable has to work," he said. "It's pretty humbling, but it makes me proud to be part of this effort." ❖



UNL physicists Aaron Dominguez (left) and Ken Bloom have leadership roles in the Compact Muon Solenoid pixel detector experiments for the Large Hadron Collider at CERN, the European Laboratory for Particle Physics, in Switzerland. They're part of UNL's particle physics team that collaborates with thousands of scientists worldwide on the Large Hadron Collider, the world's largest atom smasher. They're standing in front of an illustration of an "event" captured by the CMS detector that provided evidence of the Higgs boson. Credits: Craig Chandler, UNL photography, and Joel Brehm, UNL Office of Research and Economic Development with background image courtesy CERN.