FERMI NEWS

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Photo by Fred Ullrich

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INSIDE:

SNS: A Camera for Molecular Structures

by Kurt Riesselmann

From shatter-proof windshields to therapeutic drugs, from compact discs to cosmetics, many products have benefited from research with one of the building blocks of atoms: neutrons. Increasingly powerful neutron sources have paved the way for scientists to design and to produce new materials and better products with a wide range of applications.

Neutron diffraction studies have revealed the structure of insulin. The studies are performed on crystals of insulin molecules containing zinc ions (balls in graphic).

Image courtesy of Brookhaven National Laboratory

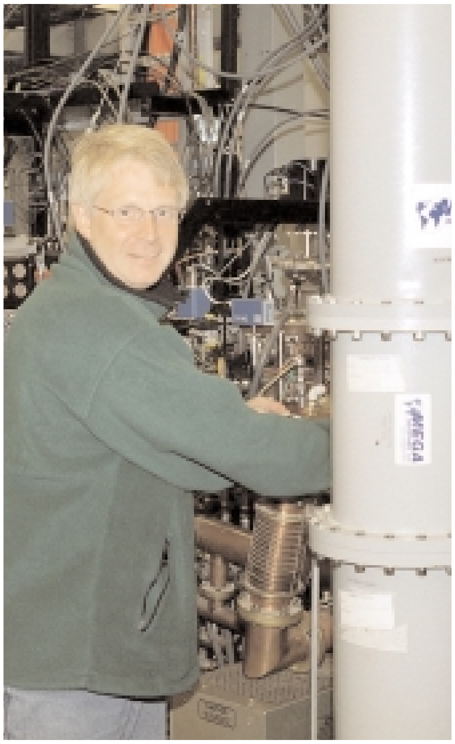


Photo by Kurt Riesselmann

Norbert Holtkamp, head of the SNS Accelerator Division

Similar to x-rays illuminating the inside of the human body, bunches of neutrons can unveil the interior of materials in a non-destructive way. Using pulsed neutron beams, scientists can even record the motion of atoms and molecules inside small samples of matter.

In contrast to x-rays, which cannot penetrate metal or other dense materials, neutrons traverse more or less all types of material, shedding light on their internal structures. For example, neutrons have been crucial in understanding how bones mineralize during development and how they degenerate during osteoporosis, a bone-demineralizing disease. The results have allowed scientists to devise and to test treatments for osteoporosis and other diseases.

"Increasingly, we are trying to master very complex materials: polymers, proteins, nanomaterials and superconductors, all of which are made of large molecules," said Thomas Mason, associate director for the Spallation Neutron Source currently under construction at Oak Ridge National Laboratory in Tennessee. "From a scientific point of view, what we need to understand is structure. Structure determines the properties of materials."

The SNS, built by the Office of Science of the U.S. Department of Energy, will be the world's premier accelerator-based neutron source, surpassing existing machines in Europe and Japan. Unlike reactor-based neutron sources, the 1.4-megawatt SNS facility, scheduled to be completed in June of 2006, will create pulses of neutrons rather than a continuous stream. Scientists will use this capability to take quick snapshots and to make "movies" of molecules in motion.

ON THE WEB:

Spallation Neutron Source
www.sns.gov

Oak Ridge National Laboratory
www.ornl.gov

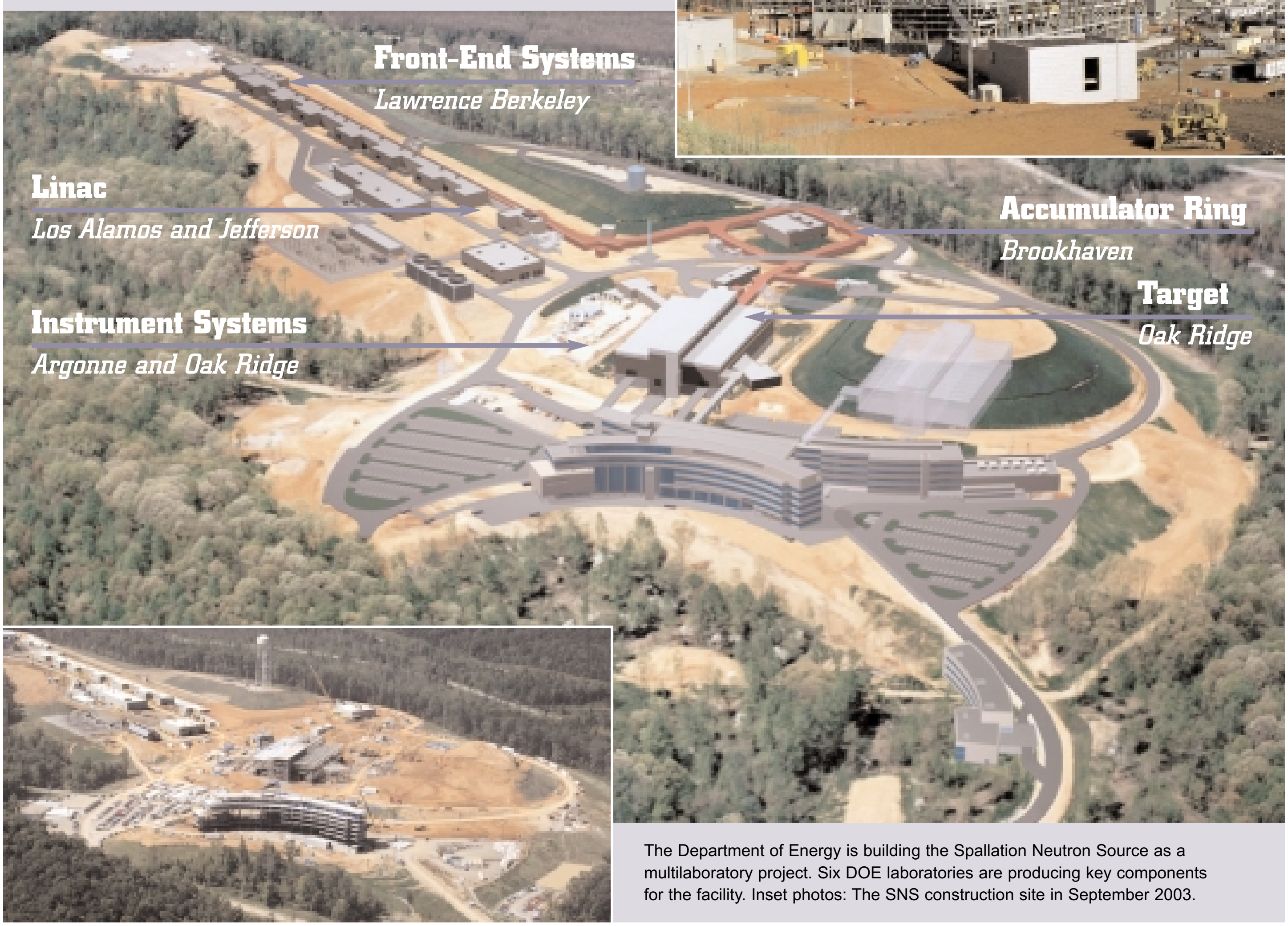
The SNS pulses will contain almost 10 times more neutrons than the most powerful, pulsed neutron source in the world, the ISIS in the U.K. With the new facility, experimenters will be able to study small amounts of physical and biological materials, advancing areas of research that deal with tiny crystals and samples. The SNS also will accommodate testing of large-scale equipment such as jet engines to study deformation and failure from prolonged stress. A future upgrade, included in the 20-year DOE science facility plan announced on November 10, would raise the power of the SNS to 2-4 megawatts.

To create neutrons, the SNS will use a 1,000-foot-long Linear Accelerator that delivers a proton beam of one GeV. An Accumulator Ring at the end of the Linac, 750 feet in circumference, receives the protons at close to the speed of light, merging and compressing them into a high-intensity proton pulse that can deliver all particles within less than a millionth of a second. Sixty times per second, the ring ejects a pulse ultimately containing more than 10^{14} protons, all of which hit a target container filled with mercury.

"It's like a snowball hitting a wall," said Norbert Holtkamp, head of the SNS Accelerator Division. "Neutrons fly out in all directions."

The proton collisions knock neutrons out of the heavy mercury nuclei, a process called spallation. On average, each proton creates about 20 neutrons. In contrast to a nuclear reactor, a spallation neutron source creates no chain reactions. Operators can stop the neutron production at any time by simply switching off the linear accelerator that provides the proton beam.

Contributors to SNS



The Department of Energy is building the Spallation Neutron Source as a multilaboratory project. Six DOE laboratories are producing key components for the facility. Inset photos: The SNS construction site in September 2003.

Photos and rendering courtesy SNS

Multilaboratory Collaboration

The construction of the SNS on an 80-acre site on top of Chestnut Ridge began in December 1999. The civil construction of all accelerator buildings is complete. The construction of the central office building and the building for the target and the instruments is in progress. According to Holtkamp, the $1.4-billion project is on budget, and more than 70 percent complete. Six DOE national laboratories contribute to the construction of the facility: Lawrence Berkeley, Los Alamos, Thomas Jefferson, Brookhaven, Argonne and Oak Ridge. ORNL is responsible for the civil construction, project management, design integration, and ultimately for operating the SNS. When completed, the SNS facility will employ about 400 permanent staff.

The installation of the accelerator components is in full progress, and SNS scientists are already testing the front-end systems built by LBNL, achieving a test beam of 2.5 MeV. Right now, particles leaving the front-end systems enter the first radiofrequency drift tube linac tank produced by LANL for the first phase of acceleration that brings the beam to 7.5 MeV. Five additional RF tanks that have already arrived at the SNS site will accelerate the beam to 87 MeV.

The remainder of the Linac features one of the big technological advances incorporated in the SNS design. Final acceleration will be achieved by superconducting RF cavities from Jefferson Lab. The cavities, cooled to 2 kelvins, have a larger aperture (beam opening) than conventional cavities, allowing higher beam intensities while reducing beam losses and residual radiation. The first three of 23 cryogenic modules, each containing three superconducting cavities, are now in the SNS Linac tunnel. Each cavity will receive power from a klystron produced in industry. Scientists expect to have the first beam passing through the entire SNS Linac in March 2005. When complete, the Linac will be the second largest RF installation in the world.

The Accumulator Ring, which collects the protons, relies on equipment produced by BNL. The ring already has received 12 of the 32 modules needed to steer the proton beam around the ring and to shape its properties. Exiting the ring, the protons will fly through a small opening into the center of the target station constructed by ORNL. The target vessel is surrounded by 15 feet of steel and concrete.

Twenty-four openings allow neutrons to escape the target area and to travel to a corresponding number of experimental areas surrounding the target station. ORNL and ANL are building five of the 24 instruments required for neutron measurements. The other instruments, at a cost of approximately $10 million apiece, will come from scientific collaborations involving universities and other scientific institutions. So far, a total of 16 instruments have been approved, none of which involve classified research. Two of the instruments will come from collaborations in Canada and Germany.

Photo by Kurt Riesselmann

About 180 employees work on the construction of the SNS accelerator and storage ring, including the former Fermilab employees (from left to right) Norbert Holtkamp, David Brown, Saeed Assadi, Alan Jones, Thomas Neustadt, Hengjie Ma, Manuel Santana and Mark Champion. Not present: Wim Blockland, John Crandall, Craig Deibele, Kerry Potter, Don Richied and Ted Williams.

Photo by Kurt Riesselmann

The first cryogenic tanks with superconducting RF cavities, built by Jefferson National Laboratory, are now in their final location within the SNS Linac.

Experts from Fermilab

Although Fermilab is not an official member of the SNS project, it provides significant expertise in form of employees and technical advice. At least 14 people working in the SNS Accelerator Division are former Fermilab employees, including Holtkamp. Since the SNS project includes the construction of the first large accelerator in the history of Oak Ridge National Laboratory, the influx of accelerator experts is more than welcome. Alan Jones, who joined Fermilab in 1972, now is breaking new ground as part of the SNS team.

“The most exciting thing is to switch things on for the first time and see them running,” he said. “Right now, we’ve got the SNS front-end systems running. We’ve produced beam.”

Of course, work at the scientific frontier on a not-yet-complete research campus has its challenges.

“At Fermilab, there was a procedure for everything,” said Mark Champion, recalling manuals and documentation associated with the scientific equipment at Fermilab. Champion, who has worked at several accelerator labs, also remembers another aspect that made work easy at Fermilab: “Fermilab has a great stockroom.”

Other former Fermilab employees responded with their own memories of a good work environment: the Fermilab Users Center, the library, the recreational facilities, the interaction with people in the cafeteria, the strong sense of community. With the main SNS office building still under construction and almost none of the expected 2,000 users on site, the SNS employees will have to wait a little longer for better amenities and a more vibrant science community. This doesn’t diminish the overall success of the SNS project so far.

“The multi-laboratory SNS partnership will likely be a model for future large science projects,” said Mason. “It will be a model for ITER, the Next Linear Collider, and other large science facilities listed in the 20-year DOE plan.”

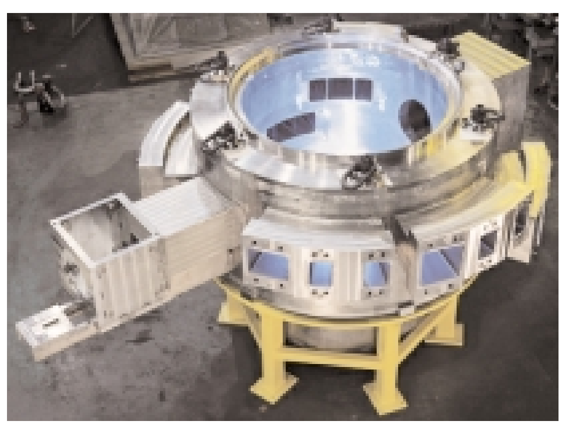


Photo courtesy SNS

A 1-GeV proton beam will hit a mercury target at the center of this vessel, creating neutrons flying in all directions. Twenty-four “windows” allow neutrons to travel to experimental set-ups surrounding the vessel.

By-Line

Science writer K.C. Cole tries her hand at experimental physics

by Matthew Hutson

"There is never, truth be told, news in physics."

These are not words you would expect to hear from a newspaper science reporter. And yet I heard them.

"It just doesn't happen that way," K.C. Cole continued. "You need to get good statistics—it takes a long time. It's a very, very slow process and you can't say at any particular point 'We found it!'"

The process of science—the building of instruments, analysis of raw data, debugging of computer code, cleaning of lenses—usually doesn't make it to the headlines. You hear "Scientists Find Top Quark," but never, "Scientists Find New Use for Mylar Tape." Experimental physicists know better than anyone the tangled marriage of serendipity and tedium in nailing down a discovery. And K.C. Cole, science writer for the *LA Times* and author, most recently, of *Mind Over Matter: Conversations with the Cosmos*, thought that as a representative for these blistered folk she should understand the relationship too. So for two and a half weeks this summer, Cole became an experimental physicist at Fermilab.

You may remember Cole from her June article in *The New Yorker* about MiniBooNE. *The New Yorker* frequently prints long articles about science, but this was the first time in recent memory that the literary institution has printed a story on experimental physics. (The more regular contributors tend not to offer much opinion on neutrino oscillations.) After helping with the story, Columbia's Janet Conrad, a consummate teacher, invited Cole to spend the summer at Fermilab. In a surprising move, Cole's editor in LA liked the idea enough to send her here for half a month.

Cole's editor, of course, expected a significant article when she got back, but Cole had more in mind than just an article. While at Fermilab, she acted not as a science writer trying to get a story but as a scientist, working in the trenches of experiment. You could call this approach embedded journalism, with obvious reference to the reporters on the front lines in Iraq, but, unlike those reporters, Cole took a direct role in the action.

Most project directors wouldn't want a newbie on the scene as more than a spectator, but Conrad offered Cole that responsibility. Len Bugel of Vermont's

ABOVE: On a well-earned break, K.C. Cole enjoys a summer day at Fermilab on her Rollerblades.

COVER PHOTO: Bill Louis, K.C. Cole, and Hyekyung Clarisse Kim working on scintillator paddles for the cosmic ray detector underneath MiniBooNE.

ON THE WEB:

MiniBooNE Experiment
www-boone.fnal.gov

The New Yorker
www.newyorker.com

from the Frontlines

Photos by Reidar Hahn

K.C. Cole, Len Bugel, and Bonnie Fleming work on a prototype for the proposed FINeSSE detector in the New Muon Lab. Fleming and Bugel are showing Cole the multiple uses of a Swiss Army Knife in experimental physics.

Stratton Mountain School, one of Conrad's collaborators, had a couple of small projects in mind in the New Muon Lab where Cole could make a contribution in the short time she had.

Bugel first paired Cole with Hyekyung Clarisse Kim, an undergraduate at Columbia, to work on the cosmic ray detectors under the 800-ton spherical vat of baby oil at the heart of MiniBooNE, or Mini Booster Neutrino Experiment. To distinguish neutrinos passing through the oil from cosmic rays, a "veto" shell surrounds the main "signal" region of the tank. Signals picked up by the veto region in effect veto simultaneous signals picked up inside the signal region. Occasionally, cosmic rays pass all the way through the tank without firing the veto detectors. Paddles of scintillating plastic lie underneath the tank and measure the veto region's inefficiency. Depending on where cosmic rays hit the paddles, experimenters can measure where the inefficiencies are located on the shell.

Cole and Kim used black tape to make the scintillators light-proof, then hooked them up to photomultiplier tubes, and finally "plateaud" the PMT's, or calibrated them so that a plot of the signal produced a clean plateau on a computer screen. Cole found this step the most frustrating.

"We had to change the voltage in tiny increments and hold everything else steady, and there was always something that went wrong. The oscilloscope wasn't working right, it was plugged into the wrong channel, the phototube was loose and we weren't getting a good connection." When they went to install the paddles, the wires didn't extend far enough, and then the holes in the floor didn't accommodate the equipment. "Every time we got to a point where we thought, 'Now we're finished,' we were never finished."

When they did finish, Cole applied her scintillator experience to Bugel's second project. A beam pipe shoots off the Booster, skirts the Main Injector tunnel and directs protons toward the MiniBooNE detector. Before the protons, clustered around the crests of radio waves, reach the detector, they hit a beryllium target and generate a spray of new particles, some of which decay into neutrinos after a "horn" funnels them into a new stream headed for the oil.

To understand certain properties of the proton beam, Bugel wanted to measure any proton "dribble" or "drool," stray protons that slid off the crests of the waves. Some protons always head off course, so he planned to set up small "telescopes" outside the beam pipe to check for strays between crests. Scintillating paddles connected to phototubes would convert photons into electrons and send a signal to a computer when it detected light. Just as before, they needed to plateau the tubes after mounting them. Cole's task, then, was to construct and calibrate the "proton dribble monitors."

Finally, Cole assisted Fermilab's Bonnie Fleming, a red-headed dynamo who, like Conrad, speaks quickly when excited and eagerly explains physics to anyone with an ear and a minute. The project: a prototype of FINeSSE, or Fermilab Intense Neutrino Scattering Scintillator Experiment, a proposed detector that would sit 100 meters from the end of the neutrino beam line. The tiny (10-ton) detector would, among other things, act as a near-detector for MiniBooNE. "This is like a mini-mini-MINOS," says Conrad. Fleming asked Cole to build a small stack of plastic scintillators, hook up the phototube, place the detector in a light-tight box, and plateau the device.

"I think she was a little surprised to find out how hard it was to get even what seem like simple things done," recalls Fleming. "How do you fix it,

Bill Louis, K.C. Cole, and Hyekyung Clarisse Kim sit under 800 tons of baby oil to work on MiniBooNE's cosmic ray detector how do you find the problem? It's a process." Fleming reminded Cole that 99 percent of physics is troubleshooting, and that everything takes "at least pi times longer than you think."

Morgan Wascko, a MiniBooNE collaborator from Louisiana State University, worked with Cole for a couple of days. "In order to give someone an idea of what it's really like, you don't want to make it all rosy like it's just a brilliant intellectual pursuit at all hours of the day. There's a lot of just hard boring work that goes into it."

In the past, Cole's writing has emphasized the beauty of nature—the prancing grace of the cosmos, the decisive grip of the strong force. She tackles big ideas and trades in metaphors. Cole begins a book describing a gap in physicists' understanding of "nothing" with the following lines:

"There is a hole in the universe.

"It is not like a hole in a wall where a mouse slips through, solid and crisp and leading from someplace to someplace. It is rather like a hole in the heart, an amorphous and edgeless void."

Describing the spectacle of science, Cole's lyrical prose stands lightyears away from its gritty laboratory origins. I asked Cole if, after a week of fixing leaks and troubleshooting equipment, she asked her mentors when the real science begins.

"I know that this is the real science," she said. "Science is so much about getting rid of the noise, getting the signal instead of the hay." Describing the work of Beams Division staff—she called them the "beam people"—Cole expressed admiration for their "incredibly intricate choreography. How delicate and fine-tuned that all has to be!" Regarding her own work, Cole wondered at how "discovery hinges on the tiniest details, like did you tape that phototube correctly? My little piece of tape is ultimately part of this grand cosmic quest."

Conrad obviously sees the same value in embedded science journalism. "When you see the finished product at a conference, it looks so clean, so neat. It all follows so well, and that's not the way it works at all. It's good for science writers to see the chaos in action."

Bugel came up with an analogy related to his passion for sports cars (especially MG's.) Last spring at a racing school he drove 30 laps in a racecar. "While I certainly didn't come out of there a racer, I came out with a whole lot more appreciation for just how much work and how much precision is involved in getting a racecar rapidly around a course."

While Cole didn't become an experimental physicist in three weeks, Bugel said, "she came away from here with a much better appreciation for the immensity and the hard work that goes into doing even a simple little measurement."

Lacking such an appreciation may lead to distortion in reporting. Describing her previous career as a political reporter, Cole told a Fermilab colloquium audience last year, "the reason I actually went into journalism at all was that I was so appalled at seeing what events were going on in Czechoslovakia or Hungary, and then watching what was written about that in the newspaper, which seemed to have absolutely nothing in common with what I saw." Although Cole doesn't say so explicitly, she seems to believe that giving a skewed view of science, of how we interrogate the world for facts and come to settle on truth, counts as just such an injustice.

So is there news in physics? Perhaps not, but there's always a good story. Cole proudly told me what Dava Sobel, author of Longitude and Galileo's Daughter, said of her once. "'K.C. Cole is our ambassador to the realms of the exceedingly strange.'" Couldn't one say the same of 60's psychonaut Timothy Leary, the Harvard scientist who explored the far reaches of experience with psychotropic drugs in search of insight? Cole laughed. "But my exceedingly strange realm is the universe," she said. "It's the real stuff. That's what's so amazing about it. The universe itself is much more amazing than anything Timothy Leary ever saw. I don't care what he was on."

"My little piece of tape is ultimately part of this grand cosmic quest"

—K.C. Cole

The Incredible Shortness of

SPPS project at SLAC creates first linac-produced x-rays

by Heather Rock Woods, SLAC Office of Public Affairs

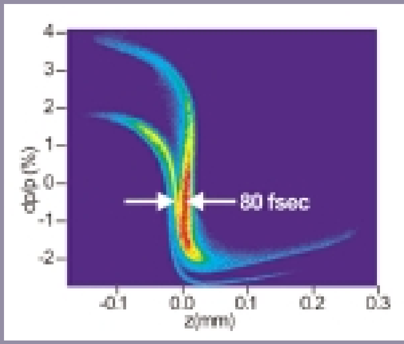
MENLO PARK, California—The world's longest linear accelerator has created the world's shortest bunches of electrons, which can be converted into bright, short pulses of x-rays to offer new views of the atomic world. These first-ever linac-produced x-rays, at Stanford Linear Accelerator Center, are 1,000 times shorter than those previously made by storage rings at SLAC, at Argonne National Laboratory and at other labs, to illuminate microscopic materials.

"These ultra-short, very bright x-rays enable experimenters to make direct observations of atomic motion in matter that have never been seen before," said Jerry Hastings, assistant director of the Stanford Synchrotron Radiation Laboratory at SLAC, which Stanford manages for the U.S. Department of Energy. Scientists in the fields of chemistry, biology and materials science, from industry, universities and other labs, can use these x-rays to take instant pictures of simple chemical reactions in progress in solids and liquids.

The project, called the Sub-Picosecond Pulse Source (SPPS), is an important stepping stone on the way to making even shorter and brighter x-rays later this decade with the world's first free electron laser (called the Linac Coherent Light Source or LCLS), which will also use the SLAC linac. The SPPS, first tested last spring, is now producing x-rays for experiments.

SPPS compresses each bunch of about 21 billion electrons from 6 millimeters down to 12 microns (millionths of a meter). Traveling at the speed of light, the bunch whizzes past a fixed point in 80 femtoseconds (quadrillionths of a second). Packing more electrons together produces more current, producing brighter x-rays. The compressed bunches reach a peak current of 30 kiloAmperes—about 1,000 times greater than the current that flows through a household fuse.

Manipulating the shape and size of electron bunches has become a science in itself. To compress the bunches, SPPS researchers rely on several tricks that can only be done at SLAC where the electrons pick up speed and energy— 28 billion electron volts—on their two-mile journey down the linac.



The simulated longitudinal phase space of the electron bunch after all three stages of compression. The horizontal axis in this image represents distance and shows an 80-femtosecond long bunch, while the vertical is relative energy (or momentum) deviation. The simulation was made using a computer code written by Michael Borland at ANL.

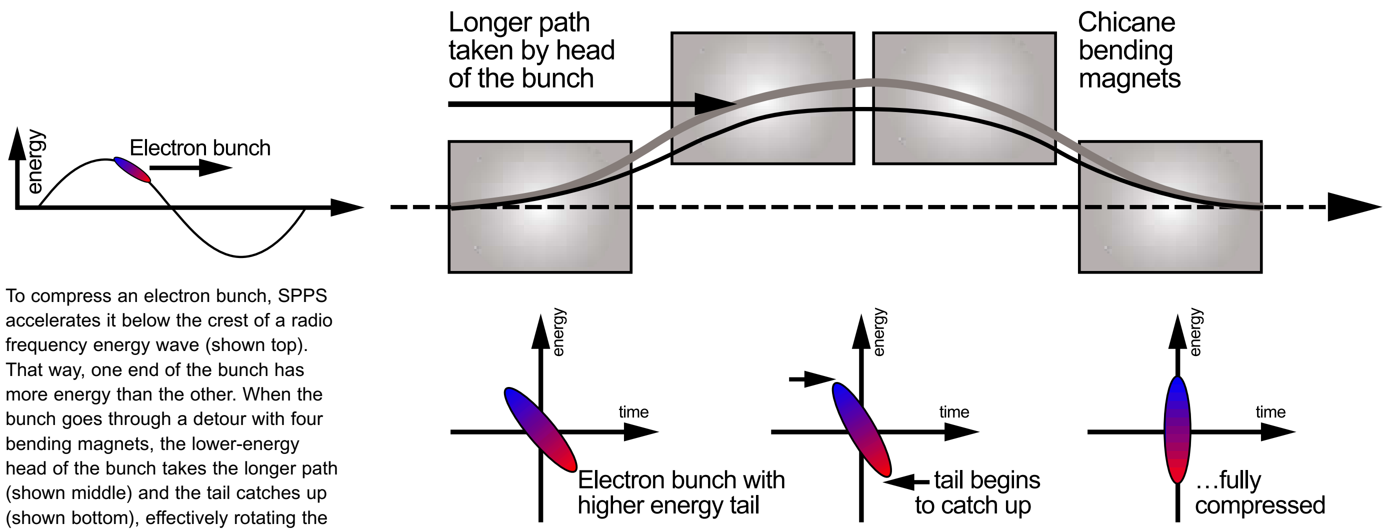
Photo courtesy of SLAC

SPPS collaborators on the world's shortest electron bunches (from left): Holger Schlarb, DESY, Paul Emma, SLAC, and Patrick Krejcik, SLAC.

ON THE WEB:

SLAC
www.slac.stanford.edu

BUNCHES



To compress an electron bunch, SPPS accelerates it below the crest of a radio frequency energy wave (shown top). That way, one end of the bunch has more energy than the other. When the bunch goes through a detour with four bending magnets, the lower-energy head of the bunch takes the longer path (shown middle) and the tail catches up (shown bottom), effectively rotating the bunch to be shorter.

Graphic by Patrick Krejcik / SLAC

"The big increase in energy from the beginning to the end of the SLAC linac allows us to do the gymnastics of rotating and compressing the bunches to reach such small final dimensions," said staff physicist Patrick Krejcik.

The gymnastics occur in three stages. First the bunches are compressed from 6 mm down to 1.2 mm in a curved section of the machine's injector, just before entering the linac. Electron bunches are usually accelerated through the linac atop radio frequency (RF) waves, similar to a surfboard riding the crest of an ocean wave. But in this first step, the bunches are adjusted to look like a surfer climbing a wave: the front of the bunch is closer to the top (and thus receives more RF energy) than the back. Going through the curved pipe, the low-energy tail takes the shortest path and catches up to the head, making the bunch shorter.

The second step is similar. Farther down the linac, where they have been accelerated to 9 billion electron volts, the bunches are tipped to ride slightly ahead of the wave crest, so the rear gets accelerated more than the front. Entering a detour (or chicane) with four bends, this time the higher-energy tail takes the shortest path and catches up again, compressing the bunch to 50 microns.

Accelerator physicist Paul Emma calculated just the right place to bend the beam to achieve this compression; as a result, the four-magnet chicane bend was installed last year. The final magnet design from engineer Cherrill Spencer surpassed tight tolerances to ensure that the new bending magnets would bend the beam without introducing optical aberrations. Linac engineer Lynn Bentson coordinated the surgical installation of the new 14-meter chicane.

But in compressing the bunches to such a degree, the team ran into technical limits. "Packing billions of electrons into a short timeframe makes them radiate together," said Emma. These highly compressed bunches lose far more energy going through the bends than would a less dense bunch. The chicane magnets were delicately balanced to make long gentle bends that minimize the energy loss of coherent synchrotron radiation while still yielding bunch compression.

The final step exploits an effect previously considered a nuisance. As the electron bunches travel at the speed of light, they generate an electric wake, similar to the wake a boat makes, called a wakefield. But instead of spreading out and dissipating, the wake made by the head of the bunch bounces off the inside of the beam pipe and interferes with the tail. This interference

BUNCHES

Photo courtesy SLAC

Stanford Linear Accelerator Center, the world's longest linear accelerator, has produced the world's shortest bunches of electrons.

creates another energy gradient between the head and tail, resulting in the final compression to 12 microns when the bunches travel through another small bend, in the Final Focus Test Beam (FFTB).

At this point, the bunches can be wiggled by an undulator magnet in order to emit x-rays (from synchrotron radiation) for studying materials. Or the electrons can be used directly to study the accelerating properties of wakefields. Engineer Eric Bong installed the undulator, on loan from Argonne. SPPS will provide ultra-short, high-current pulses alternately to these two programs for the next two years.

SPPS is an international collaboration that includes laboratory and university participants from the United States and abroad. SLAC is working closely with the *Deutsches Elektronen Synchrotron* (DESY) lab in Germany to develop instrumentation for tuning and optimizing the bunches. DESY is also planning a free electron laser similar to the LCLS.

"We need a way to measure the bunch length, so part two of the project is inventing new technologies to measure on the sub-picosecond timescale," Krejcik said.

One technology is actually an old one: the group resuscitated a specialized accelerator cavity used at SLAC in the 1960's to kick the beam vertically. They inserted transverse deflecting cavity was into the beam line. When powered by a klystron, it samples a bunch by sweeping the bunch vertically across a screen where the vertical size gives a projection of bunch length after the second compression. The collaboration is developing electro-optic sampling techniques, borrowed from the world of fast laser technology, to measure the fully compressed bunches in the FFTB line.

"We're starting with demonstration experiments now, and learning techniques that will be vital for exploiting LCLS. We're generating an ultra-fast community at SLAC, and stimulating interest in ultra-fast x-ray science internationally," said SSRL physicist John Arthur.

"SPPS is relatively inexpensive." Emma said. "It uses the existing linac and it solves important problems, including making LCLS more plausible."

Auger Observatory becomes world's largest air shower array

Tracking Down Cosmic Rays

by Kurt Riesselmann

The Pierre Auger Observatory, under construction in Argentina, became the largest cosmic-ray air shower array in the world with the completion of its one hundredth surface detector in October. Managed by Fermilab, the Pierre Auger project so far encompasses a 70-square-mile array of detectors that are tracking the most violent-and perhaps most puzzling- processes in the entire universe.

Cosmic rays are extraterrestrial particles—usually protons or heavier ions—that hit the Earth's atmosphere and create cascades of secondary particles. While cosmic rays approach the earth at a range of energies, scientists long believed that their energy could not exceed 10^{20} electron volts, some 100 million times the proton energy achievable in Fermilab's Tevatron, the most powerful particle accelerator in the world. But recent experiments in Japan and Utah have detected a few such ultrahigh energy cosmic rays, raising questions about what extraordinary events in the universe could have produced them.

Fermilab Photo

In October 2003, Argentinean technicians finished the installation of the 100th surface detector, making the Pierre Auger Observatory the largest cosmic-ray experiment in the world.

"How does nature create the conditions to accelerate a tiny particle to such an energy?" asked Alan Watson, physics professor at the University of Leeds, UK, and spokesperson for the Pierre Auger collaboration of 250 scientists from 14 countries. "Tracking these ultrahigh-energy particles back to their sources will answer that question."

Scientific theory can account for the sources of low- and medium-energy cosmic rays, but the origin of these rare high-energy cosmic rays remains a mystery. To identify the cosmic mechanisms that produce microscopic particles at macroscopic energy, the Pierre Auger collaboration is installing an array that will ultimately comprise 1,600 surface detectors in an area of the Argentine Pampa Amarilla the size of Rhode Island, near the town of Malargüe, about 600 miles west of Buenos Aires. The first 100 detectors are already surveying the southern sky.

"These highest-energy cosmic rays are messengers from the extreme universe," said Nobel Prize winner Jim Cronin, of the University of Chicago, who conceived the Auger experiment together with Watson. "They represent a great opportunity for discoveries."

The highest-energy cosmic rays are extremely rare, hitting the Earth's atmosphere about once per year per square mile. When complete in 2005, the Pierre Auger observatory will cover approximately 1,200 square miles (3,000 square kilometers), allowing scientists to catch many of these events.

ON THE WEB:

Pierre Auger Observatory
www.auger.org

Two Mysteries, One Solution?

Dark matter quest could lead to supersymmetry

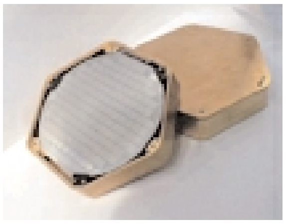
by Matthew Hutson

Project manager Dan Bauer from Fermilab holds one tower of detectors as Vuk Mandic from UC Berkeley examines them.

Using detectors chilled to near absolute zero, from a vantage point half a mile below ground, physicists of the Cryogenic Dark Matter Search announced the November 12 launch of a quest that could lead to solving two mysteries that may turn out to be one and the same: the identity of the dark matter that pervades the universe, and the possible existence of supersymmetric particles.

Scientists of CDMS II, an experiment managed by Fermilab, hope to discover WIMPs, or weakly interacting massive particles, the leading candidates for the constituents of dark matter-which may be identical to neutralinos, undiscovered particles predicted by the theory of supersymmetry.

"There's this arrow from particle physics and this arrow from cosmology and they seem to be pointing to the same place," said Case Western Reserve University's Dan Akerib, deputy project manager of CDMS II. "Detection of a neutralino would be very big for cosmology and it would also be very big for particle physics."



Individual silicon detectors like these operate in stacks at close to absolute zero.

The CDMS II experiment, a collaboration of scientists from 12 institutions with support from DOE's Office of Science and the National Science Foundation, uses a detector located deep underground in the historic Soudan iron mine in northeastern Minnesota. Experimenters seek signals of WIMPs, particles much more massive than a proton but interacting so weakly with other particles that trillions would pass through a human body each second without leaving a trace.

Remarkably, in the kind of convergence that gets physicists' attention, the characteristics of this cosmic missing matter particle now appear to match those of the supersymmetric neutralino.

"Either that is a cosmic coincidence, or the universe is telling us something," said Fermilab's Dan Bauer, CDMS II project manager.

By watching how galaxies spin-how gravity affects their contingent stars-astronomers have known for 70 years that the matter we see cannot constitute all the matter in the universe. If it did, galaxies would fly apart. Recent calculations indicate that ordinary matter containing atoms makes up only 4 percent of the energy-matter content of the universe. "Dark energy" makes up 73 percent, and an unknown form of dark matter makes up the last 23 percent.

"It is often said that this is the ultimate Copernican Revolution," said David Caldwell, a physicist at the University of California at Santa Barbara and chair of the CDMS Executive Committee. "Not only are we not at the center of the universe, but we are not even made of the same stuff as most of the universe."

Measurements of the cosmic microwave background, residual radiation left over from the Big Bang, have recently placed severe constraints on the nature and

CDMS Institutions

CDMS II collaborators include Brown University, Case Western Reserve University, Fermi National Accelerator Laboratory, Lawrence Berkeley National Laboratory, National Institute of Standards and Technology, Princeton University, Santa Clara University, Stanford University, University of California at Berkeley, University of California at Santa Barbara, University of Colorado at Denver, University of Minnesota.

ON THE WEB:

CDMS home page
http://cdms.berkeley.edu/index.html

CDMS background information
www.fnal.gov/pub/presspass/press_releases/CDMS_Background.html

amount of dark matter. The lightweight neutrino can account for only a few percent of the missing mass. If neutrinos constituted the main component of dark matter, they would act on the cosmic microwave background of the universe in ways that the recent Wilkinson Microwave Anisotropy Probe should have observed-but did not.

Meanwhile, particle physicists have kept a lookout for particles that will extend the Standard Model, the theory of fundamental particles and forces. Supersymmetry, a theory that takes a big step toward the unification of all of the forces of nature, predicts that every matter particle has a massive supersymmetric counterpart. No one has yet seen one of these “superpartners.” Theory specifies the neutralino as the lightest neutral superpartner, and the most stable, a necessary attribute for dark matter. The neutralino’s predicted abundance and rate of interaction also make it a likely dark matter candidate, and Caldwell noted the impact that CDMS II could have.

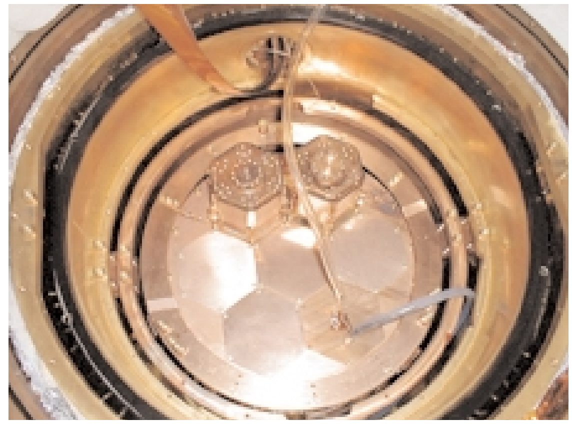
“Discovery,” he said, “would be a great break-through, one of the most important of the century.”

Only occasionally would a WIMP hit the nucleus of a terrestrial atom, and the constant background “noise” from more mundane particle events-such as the common cosmic rays constantly showering the earth-would normally drown out these rare interactions. Placing the CDMS II detector beneath 740 meters of earth screens out most particle noise from cosmic rays. Chilling the detector to 50 thousandths of a degree above absolute zero reduces background thermal energy to allow detection of individual particle collisions. Fermilab’s Bauer estimates that with sufficiently low backgrounds, CDMS needs only a few interactions to make a strong claim for detection of WIMPs.

“The powerful technology we deploy allows an unambiguous identification of events in the crystals caused by any new form of matter,” said CDMS cospokesperson Bernard Sadoulet of the University of California at Berkeley.

Cospokesperson Blas Cabrera of Stanford University concurred.

“We believe we have the best apparatus in the world in terms of being able to identify WIMPs,” Cabrera said.



A view of the inner layers of the cryostat with two towers installed.

As a significant inter-agency effort, CDMS II is funded by the Office of Science of the U.S. Department of Energy, and by the Astronomy and Physics Division of the National Science Foundation.

“This endeavor is a good example of cooperation between the DOE’s Office of High Energy Physics and the National Science Foundation in helping scientists address the origin of the dark matter in the universe,” said Raymond Orbach, Director of the Department of Energy’s Office of Science.

“CDMS II is the kind of innovative and pathbreaking research NSF is proud to support,” said Michael Turner, Assistant Director for Math and Physical Sciences at the National Science Foundation. “If it detects a signal it may tell us what the dark matter is and give us an important clue as to how gravity fits together with the other forces. This type of experiment shows how the universe can be used as a laboratory for getting at the some of the most basic questions we can ask as well as how DOE and NSF are working together.”

While CDMS II watches for WIMPs, scientists at Fermilab’s Tevatron particle accelerator will try to create neutralinos by smashing protons and antiprotons together.

“CDMS can tell us the mass and interaction rate of the WIMP,” said collaborator Roger Dixon of Fermilab. “But it will take an accelerator to tell us whether it’s a neutralino.”

FERMI NEWS

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A BAROQUE CHRISTMAS - AULOS ENSEMBLE WITH JULIANNE BAIRD

December 6, 2003

Tickets - $22 ($11 ages 18 and under)

"Authentic Baroque performances at its best. If there has to be one Christmas concert, this is it." - The New York Times

For a Holiday treat that is a little out of the usual, join us for A Baroque Christmas with the Aulos Ensemble and special guest, soprano Julianne Baird. This group has performed annual Christmas concerts at the Metropolitan Museum of Art that have been called "one of the most charming musical celebrations of the season in New York."

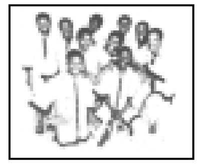
LADYSMITH BLACK MAMBAZO

Saturday, February 14, 2003

Tickets - $27 ($14 for ages 18 and under)

"Its seven bass voices and two of its three tenors sang such close harmonies and with such subtle nuances that they sounded like one deep, rich, resonant and proud voice." - The New York Times

It has been more than fifteen years since Paul Simon made his initial trip to South Africa and met Joseph Shabalala and the other members of Ladysmith Black Mambazo in a recording studio in Johannesburg. Simon incorporated the traditional sounds of black South Africa into the *Graceland* album, a project regarded by many as seminal to



today's explosive interest in World Music. Ladysmith Black Mambazo has come to represent the traditional culture of South Africa. Considered South Africa's cultural emissaries at home and around the world, Black Mambazo accompanied the future President Nelson Mandela, and then-South African President F.W. de Klerk, to the Nobel Peace Prize ceremony in Oslo, Norway in 1993. Mambazo sang again at President Mandela's inauguration in May of 1994. They are a national treasure of the new South Africa in part because they embody the traditions suppressed in the old South Africa.

MILESTONES

RETIRING

- Terrence O'Brien (ID 2166, PPD-Electrical Engineering Department), effective Dec. 1, 2003.
- Vanetta Readus (ID 3070, BS-SU-Dist/Receiving/Shipping), effective Jan. 7, 2004. Her last day of work was Oct. 31, 2003.

Chez Léon MENU

LUNCH SERVED FROM
11:30 A.M. TO 1 P.M.
$10/PERSON

DINNER SERVED AT 7 P.M.
$23/PERSON

FOR RESERVATIONS, CALL X4512
CAKES FOR SPECIAL OCCASIONS
DIETARY RESTRICTIONS
CONTACT TITA, X3524
HTTP://WWW.FNAL.GOV/FAW/EVENTS/MENUS.HTML

LUNCH
WEDNESDAY, DECEMBER 3

Curried Cornish Game Hens
Lentil Rice
Vegetable of the Season
Dutch Butter Cake

DINNER
THURSDAY, DECEMBER 4

BOOKED

LUNCH
WEDNESDAY, DECEMBER 10

Stuffed Pork Loin with Linden berry Sauce
Braised Red Cabbage
Roasted New Potatoes
Ginger Molasses Spice Cake

DINNER
THURSDAY, DECEMBER 11

Lobster Bisque
Duck Breast with Raspberry Port Sauce
Nutted Wild Rice
Stir Fried Vegetables with Orange & Mint
Cranberry Napoleon

LUNCH
WEDNESDAY, DECEMBER 17

Christmas Lunch with Santa
12:00 NOON
Seafood Strudel with Christmas Vegetables
Vanilla Flan with Raspberry Sauce

DINNER
THURSDAY, DECEMBER 18

Christmas Dinner with Santa
Chestnut Soup with Cognac Cream
Lobster Medallions with Champagne Butter Sauce
Sauteed Christmas Vegetables
Spinach and Pomegranate Salad
Raspberry Parfait with Christmas Cookies

LUNCH
WEDNESDAY, DECEMBER 24

CLOSED

DINNER
THURSDAY, DECEMBER 25

CLOSED

CHRISTMAS DAY

http://www.fnal.gov/pub/ferminews/

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