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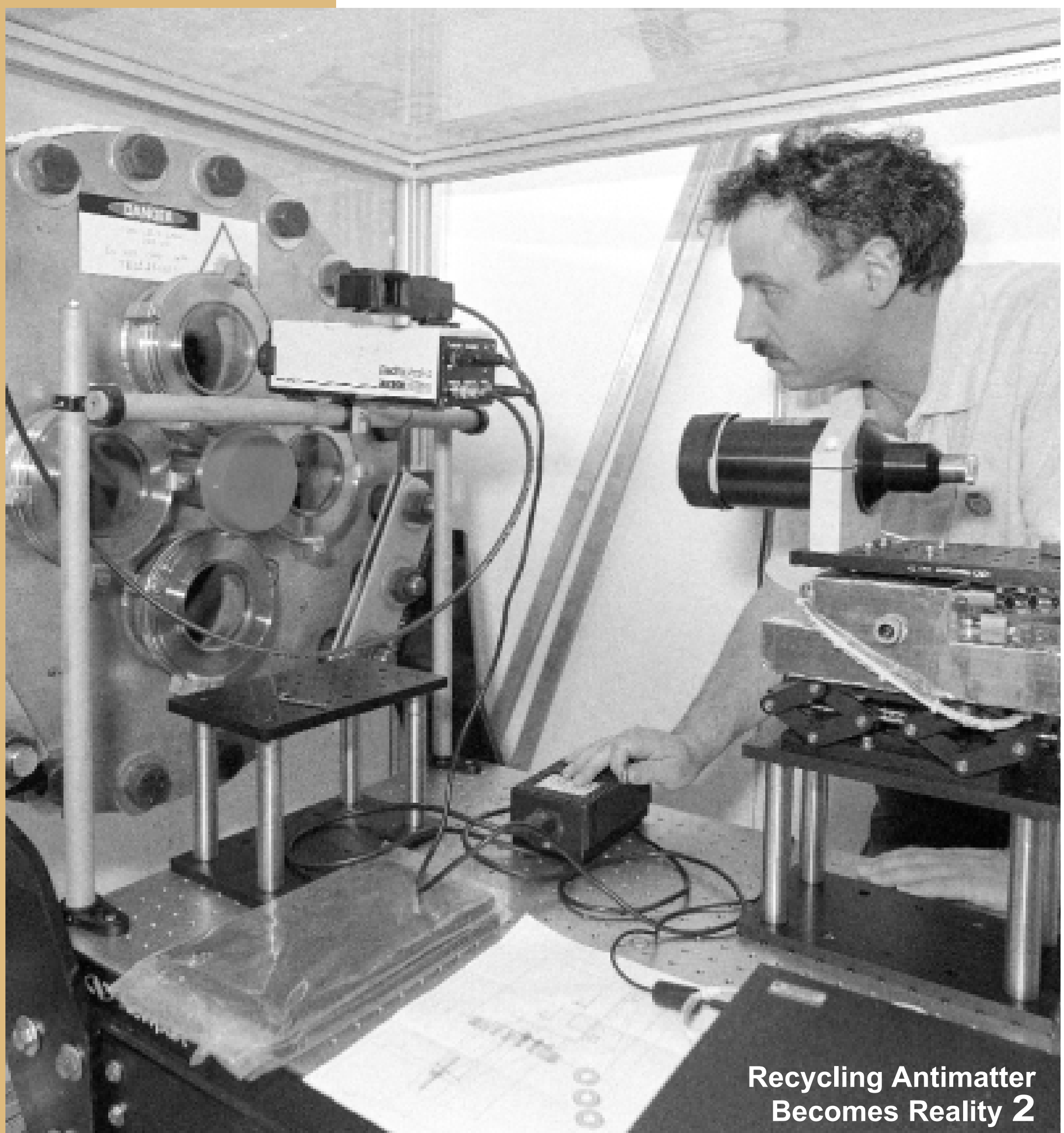

Recycling Antimatter Becomes Reality 2

Photo by Reidar Hahn

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Recycling ANTI MATTER Becomes REALITY

Photo by Reidar Hahn

The box-shaped magnets for the Recycler Ring, designed to store antiprotons close to the speed of light, sit atop the Main Injector, which accelerates protons and antiprotons from 8 to 150 GeV.

by Kurt Riesselmann

Antimatter is arguably the rarest stuff Mother Nature provides here on earth. Created in high-energy particle collisions, antiparticles quickly disappear by reacting with ordinary matter. Using powerful accelerators, physicists have learned to produce and control tiny amounts of antimatter. The yield, however, is less than a microgram per year, and antiparticles remain a precious commodity.

Scientists at Fermilab are now taking a new approach to satisfy the ever-increasing demand for antimatter: they will recycle antiprotons. To maximize the use that experimenters can get out of the antimatter created at the lab, scientists have built a storage ring, the Recycler, in which they can inject antiprotons that have survived many hours of collision experiments. When the experiments receive the subsequent batch of antiparticles, the beam will contain recycled antiprotons – assuming scientists manage to keep the antiprotons "alive" inside the Recycler for a long enough time.

"As of now, we've achieved a lifetime of greater than forty hours," said Shekhar Mishra, who heads the Main Injector Department and Recycler Commissioning. "And plans are already in place to improve the lifetime by at least a factor of three."

Things looked less promising as few as three months ago, when the lifetime was a mere nine hours. The innovative and energy-saving design of the Recycler relies on a two-mile-long ring of permanent magnets to steer antiprotons through a two-inch-wide beam pipe. Imperfections in the alignment and the absence of adjustable electromagnets have made it difficult to keep antiprotons on track as they fly close to the speed of light through the vacuum-filled Recycler beam pipe, about 100,000 times per second. Too many antiprotons were lost due to contact with the pipe.

"The Recycler is only a success if the beam goes around many billions of times," said Fermilab physicist Bill Foster, who worked on a smaller beam line with permanent magnets in the past. "People didn't realize how hard it would be to align the beam pipe between the permanent magnets so that the beam can go through. It is a tremendous amount of work to put things together the way it was meant."

INTERNATIONAL HELP

In Spring 2001, Mishra and other Recycler experts began to make plans for major improvements to the antiproton storage ring. Clearly, the magnets and the beam pipe needed to be aligned with greater precision. In addition, the group wanted to install corrector magnets, spares that Fermilab had received from CERN, the European particle physics laboratory, which was disassembling its LEP accelerator. Finding enough people to carry out this work proved to be the critical factor.

"We knew what we needed to do," said Mishra. "But we could only have five to six weeks of access to the tunnel that hosts the Recycler. We had to

"They **COME TO US** with their requests and then **we turn them into REALITY**."

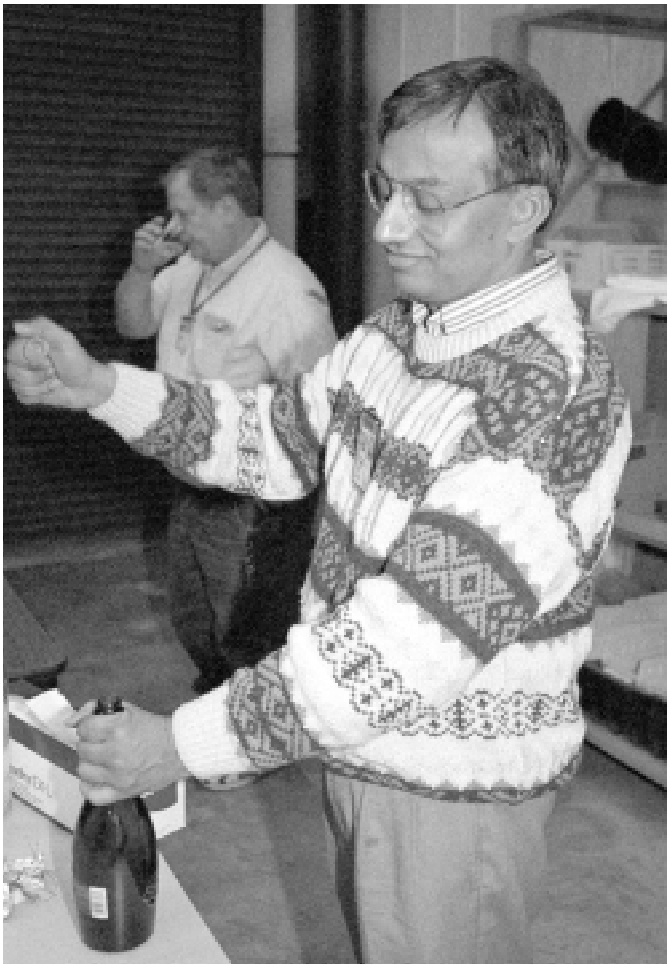
—Dave Augustine, Fermilab Mechanical Support

Photo by Jenny Mullins

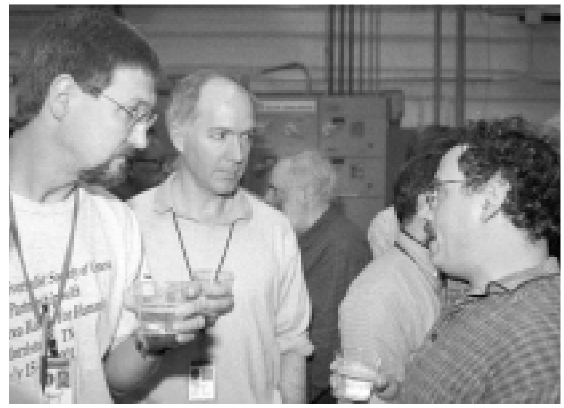
During a six-week period last fall, more than 80 technicians worked on improving the Recycler storage ring. They worked in two shifts to align old and install new equipment in the two-mile-long tunnel.

"The **RECYCLER** is in GOOD SHAPE. We now have **both BELTS and SUSPENDERS.**"

– Bill Foster, Fermilab physicist



The great boost in performance of the antiproton storage ring at Fermilab has given Shekhar Mishra, head of the Main Injector Department, a good reason to celebrate.



Photos by Reidar Hahn

Dave Johnson (left), Bill Foster and Ralph Pasquinelli discuss the success the Recycler group has had so far.

look for additional people to get the work done during shutdown time."

A call for help went to all Fermilab divisions as well as particle physics institutions around the world, and the response was overwhelming.

"We received offers from the University of Pennsylvania and the University of Glasgow, Scotland," recalled Dave Augustine, who coordinated the work of all technicians during the shutdown. "We also had offers from Germany, Russia and other countries. I had more volunteers than I could use. Many department heads at Fermilab also pared down their to-do lists, making their personnel available for the shutdown. We trimmed it to roughly 90 people, about 40 people beyond our own group. We got help from top-notch, willing individuals. They were fun people to be around. I miss them."

The technicians worked at various locations inside the two-mile tunnel that hosts the Recycler. To complete the alignment work on time, Augustine enlisted the help of every surveyor of the Fermilab survey group, organizing their work in two shifts. Cons Gattuso coordinated the technical aspects of the tunnel work, consulting with other scientists and beam experts. And the preparations paid off.

"We planned very carefully," said Mishra. "If a screw needed to be ordered, it was there on time. All the jobs on my list got done. It couldn't have happened without the help of these people. They knew how important this was. And they were all very professional. We had no accidents."

LIFETIME INCREASES DRAMATICALLY

The upgrades had the desired impact on the performance of the Recycler. All magnets and beam pipe sections are now aligned to one tenth of a millimeter, ten times better than before the shutdown. And the correctors give scientists additional control of the beam to minimize beam losses.

"The alignment problems and the lack of correctors was a double whammy," Foster pointed out. "Now the Recycler is in good shape. We now have both belts and suspenders."

Despite the progress, Mishra and Foster are not yet content with the Recycler.

“We need a lifetime of more than 100 hours,” said Mishra. “If we improve the vacuum by a factor of three, it’s do-able. We are going to have another shutdown, probably in July, to upgrade the Recycler even more.”

At present, the vacuum inside the beam pipe is not as good as hoped for. There are still gases like argon and water vapor inside the pipe. They reduce the lifetime of the antiproton beam as antiprotons collide with the gas particles. Adding special heavy-ion vacuum pumps to the Recycler, scientists can eliminate the argon, which is a residue from welding the beam pipe. To “bake out” the traces of water vapor, technicians surrounded the beam pipe with special heating tape. During the next shutdown, scientists will heat the beam pipe to more than 240°F. Additionally, crews are looking for tiny air leaks, but they haven’t found any yet.

This fall, Mishra’s group expects to integrate the Recycler into daily Fermilab accelerator operations. Initially, scientists will use the Recycler to store new antiprotons. Actually recycling antiprotons will be the second phase. It will increase the number of proton-antiproton collisions inside the Tevatron, the world’s most powerful particle accelerator, by a factor of two to three, significantly improving the chance that experimentalists may find the elusive Higgs boson or some new building block of nature in the next several years.

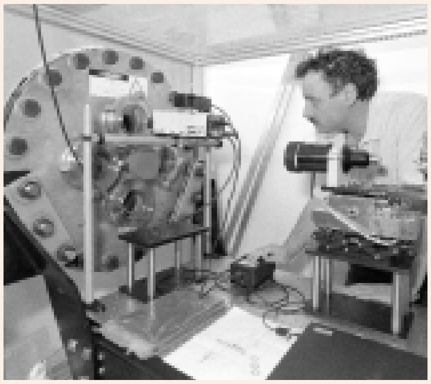
“The Recycler is an integral part of achieving the Run II goals that the lab has set for itself in collaboration with the Department of Energy,” said Ron Lutha, a manager at the local DOE office, who had supervised the civil construction of the Recycler. “We have a long way to go. But the more antiprotons you have out there to smash together the better.”

Thanks to all the people helping during the recent Recycler upgrade, the day is near that no antiproton will go to waste.

On the Web:
Beams Division
www-bd.fnal.gov

Live Status of Accelerators
www.fnal.gov/pub/now/

Keeping Antiprotons COOL



COVER PHOTO: Ralph Pasquinelli has worked on the stochastic cooling system for the Recycler Ring. It uses laser signals, sent from one side of the ring to the other, to steer equipment that shapes the circulating particle beams.

Scientists judge the performance of the Recycler by the lifetime of the antiprotons that circle the storage ring. If an antiproton doesn’t encounter any ordinary matter, it will exist forever.

In practical terms, however, it’s challenging to keep a beam of antiprotons from interacting with other particles. First, a beam constantly hits residual particles in the less-than-ideal vacuum inside the beam pipe. Second, small fluctuations in the motion increase the size of the antiproton beam despite the fact that the number of antiprotons remains constant. Like cars in a high-speed bumper car race, antiprotons get pushed out of the ideal path as the beam becomes more random, causing antiprotons to crash into the surrounding beam pipe.

Scientist use the concept of stochastic cooling, a Nobel Prize-winning idea, to reduce the random motion, minimizing the differences in momentum among beam particles and making the size of the beam physically smaller.

“Inside the Recycler beam pipe, we’ve installed microwave antennas,” said Ralph Pasquinelli. “They sense the size of the beam and the spread in momentum. Their signals are transferred across the ring, where a corrective signal is applied to the beam.”

Since the antiprotons travel close to the speed of light, it’s a challenge to get the signal across the ring before the antiprotons have passed by. Standard electrical cables are far too slow to transfer the signal. Fiberoptic cables also fail as they transmit signals at far less than the speed of light in vacuum. The only solution fast enough is a straight beam of light itself. At the Recycler, scientists use the antenna signals to modulate an infrared laser beam that shines through a 2,000-foot-long pipe across the Recycler ring. At the end of the pipe the signals are transformed back into electrical signals, which steer the equipment that nudges the beam.

“Without cooling, the lifetime of the antiprotons would be in the teens of hours compared to the forty-plus hours we’ve achieved so far,” Pasquinelli explained. “We have made great progress, but there is still a lot to learn.”

–Kurt Riesselmann

On the Web:
1984 Nobel lecture on stochastic cooling:
www.nobel.se/physics/laureates/1984/meer-lecture.html

SCIENCE *Finds a Warm Small-Town Welcome* in Malargüe

by Paul Mantsch
Pierre Auger Observatory

The Southern Hemisphere site of the Pierre Auger Observatory is composed of 1,600 particles detectors spread over about a thousand square miles in a very flat part of Mendoza Province, Argentina near a town called Malargüe. We are using the observatory to probe the mysteries of extremely high-energy cosmic rays, very rare particles striking the top of the atmosphere and creating showers of billions of secondary particles that strike the earth. We hope to capture thousands of these events over the next 20 years.

The people of Malargüe have already captivated us.

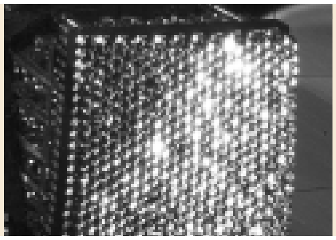
A town of eight thousand people, Malargüe is nestled between the foothills of the Andes Mountains and a vast arid plain known as the Pampa Amarilla. The nearest large town is 125 miles away, with a single gas station in between. Malargüe's fortunes have risen and fallen with booms in mining and oil. Unemployment is currently greater than twenty percent. The community sustains itself on the remnants of the oil business, and on ranching and tourism. Malargüe is a pleasant town of warm, friendly people. Crime and other ills of larger cities are rare. There is an abundance of well-educated and skilled workers. A variety of businesses provide services, and good hotels and restaurants remain from the era of past prosperity.

The provincial governor, local mayors and even the president of the country worked hard to bring the Auger Project to Argentina, promising funds for construction and the support of strong physics groups. During our first visits, we were feted with an abundance of Mendoza wine, barbecued spring goat and other specialties of the area. The Malargüe tourist office provided invaluable help, offering their spacious new convention center for our collaboration meetings. The province of Mendoza gave us a beautiful site for our campus, a former tree nursery lined by 60-foot-high poplars.

We began at once to engage the community, meeting with residents and particularly with the ranchers from whom we needed to rent space for our detectors. We offered presentations by our Spanish-speaking collaborators. They were a great hit, attracting overflow crowds of all ages.

We made a special effort to connect with the schools. The people of Malargüe value education highly and have a good school system. Our collaborators visited the schools to make presentations about the project and general science. Students and teachers at several English-language institutes were intrigued. With native English speakers rare, the students eagerly tested their skills on any scientist they could corner.

Photos courtesy Pierre Auger Observatory



The clock tower presides over the Malargüe town square. Top row, from left: Mayor Celso Jaque makes a presentation at the dedication of the Pierre Auger Observatory headquarters building. The new building houses offices and the data acquisition center. Visitors to the new center view posters explaining the experiment. Bottom row, from left: Visitors to the new building can view the camera and other equipment used in the experiment. For the ribbon-cutting ceremony, people gathered inside and outside the new Detector Assembly Building.

We had begun naming our detector stations after old girl friends, but we soon ran out of names. Someone suggested having the elementary school children name the detector tanks, and the contest caused lots of excitement. Each entry included a drawing, showing the student's impression of the observatory and its purpose. Michigan Technical University, an Auger collaborating institution, offered a full scholarship to a student from Malargüe, to be followed by another every two years, with a local committee selecting the candidate—big news in this remote town. The first student is now in his freshman year at MTU and doing very well.

Not only the children have felt the influence of the project. With Auger came a jump in the enrollment of adults at the English language institutes. Shopkeepers were anxious to be able to speak with the scientists coming into their shops. On the bus to Malargüe, an Auger collaborator asked a weathered old gaucho next to him if he knew anything about the project, and was rewarded with a somewhat confused but very enthusiastic description.

We included a visitor center when designing the new building to house our offices and data acquisition center. Pieces of our experimental equipment and explanatory posters are on display. The inauguration ceremonies for the new building attracted a thousand townspeople, the first of a steady stream of visitors.

We asked Mayor Celso Jaque if the expectations of the people of Malargüe had been met in the three years since Auger came to town. He said that, although the townspeople have little detailed understanding of what the Auger Project is about, they are extremely proud to have it in Malargüe. At first they weren't sure that anything would actually happen. They had recently been disappointed when an international mining project fizzled. However, when they saw scientists arriving from all over the world and buildings beginning to rise, their hopes were realized. They understand that the Auger Project will certainly not bring the kind of prosperity of the oil boom but see other, less tangible, but important benefits. They appreciate the close association with Auger scientists and engineers and the contacts with the outside world. They are proud that Malargüe is becoming known around the world as a center for science. Amid the discouragement and hardship of Argentina's economic crises, these connections keep spirits up and serve as a source of hope for the future.

Malargüe cannot boast an airline link or a symphony orchestra or other advantages we may take for granted at home. But it is hard to imagine a better match than the town and people of Malargüe and the Pierre Auger Project.

On the Web

The Pierre Auger Observatory
http://www.auger.org/

High Schools JOIN THE SEARCH for MOST ENERGETIC Particles in the Universe

by Greg Snow
University of Nebraska

Photo by Michael Brands

Before taking off in a balloon at Snowmass last summer, Heather Zorn (left), Greg Snow, Jeffrey Wilkes and Hans Berns compare notes and repair instrumentation with state-of-the-art duct tape.

They were looking for extra-terrestrials, and they weren't going to quit just because the clock said 5:00 p.m. on a beautiful summer afternoon in the Rocky Mountains.

These high school teachers and students had been working for hours, assembling their scintillation detectors, checking them for light leaks with flashlights and oscilloscopes, and calibrating them for the appropriate discriminator thresholds. They weren't expecting a phone call from ET, or "Contact" with Jodie Foster, but they were on the verge of making their first observation of a bona fide, real-life extraterrestrial—a high-energy cosmic ray that had traveled to earth from a distant galaxy.

The scene was Snowmass, Colorado last July 19. The gathering was the week-long workshop to inaugurate SALTA, the Snowmass Area Large-scale Time-coincidence Array. The SALTA workshop was one ingredient in the Education and Outreach project, organized by Elizabeth Simmons of Boston University, associated with the 2001 Summer Study on the Future of High Energy Physics.

The workshop's goal was to plant seeds in Colorado and Illinois, hoping the seeds will grow into full-scale members of the North American Large-scale Time-coincidence Array—a continent-wide consortium of partnerships between university physics departments and nearby high schools to study extensive cosmic-ray air showers, an exciting subfield of frontier astro-particle physics research.

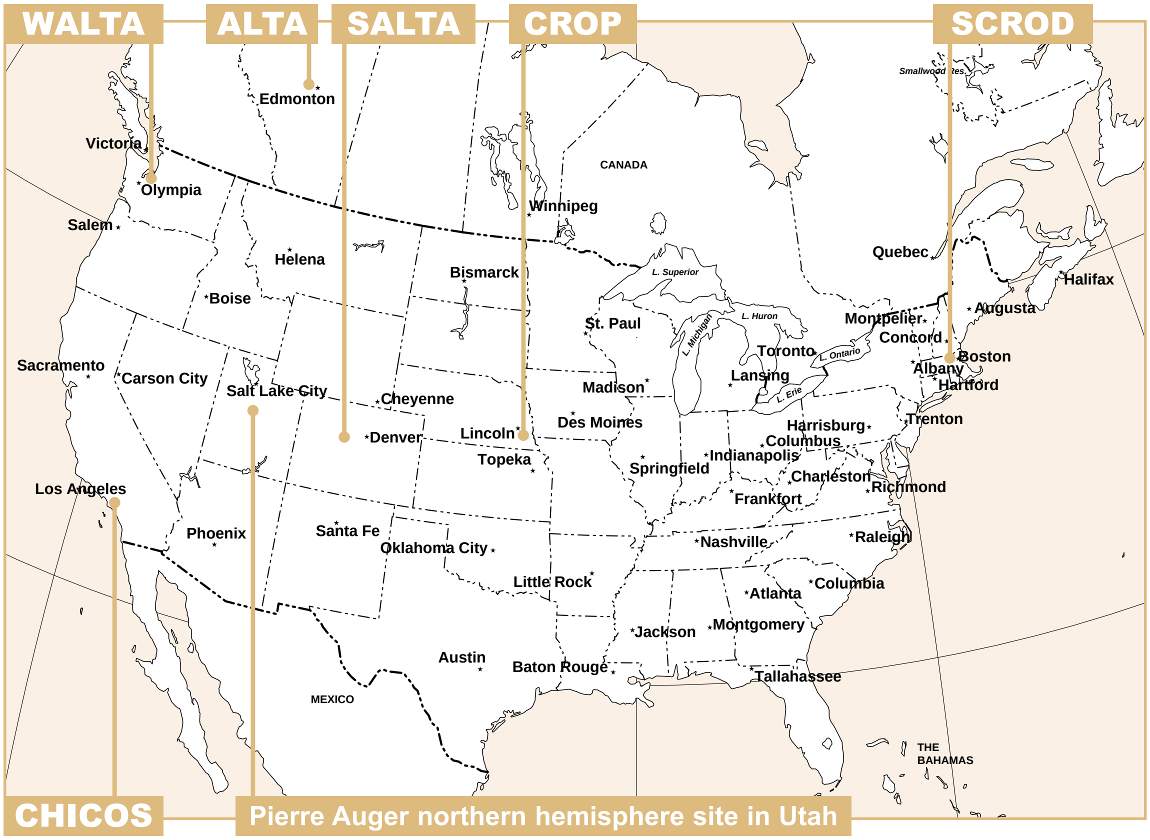
The origin and acceleration mechanism for ultra high energy cosmic rays are unknown, but they clearly must come from a catastrophic astrophysical phenomenon, such as an active galactic nucleus or the collision of two remote galaxies. It is possible that when one UHECR strikes the earth, it is accompanied by a burst of such particles that could shower an entire continent. We can only see them with detectors distributed over very large distances, all operating simultaneously with GPS time-stamping of their recorded events—exactly as the NALTA arrays will operate. But even if we do not observe such fantastic bursts, we can at least set a limit on the frequency of their occurrence—a legitimate and important scientific result.

Greg Snow is a physicist on DZero and the Pierre Auger Observatory, and a member of Fermilab's Board of Overseers. He runs the Cosmic Ray Observatory Project in Nebraska with colleague Daniel Claes.

On the Web

North American Large-scale Time-coincidence Array, with links to each regional project home page

http://csr.phys.ualberta.ca/nalta/



NALTA– North American Large-scale Time-coincidence Array

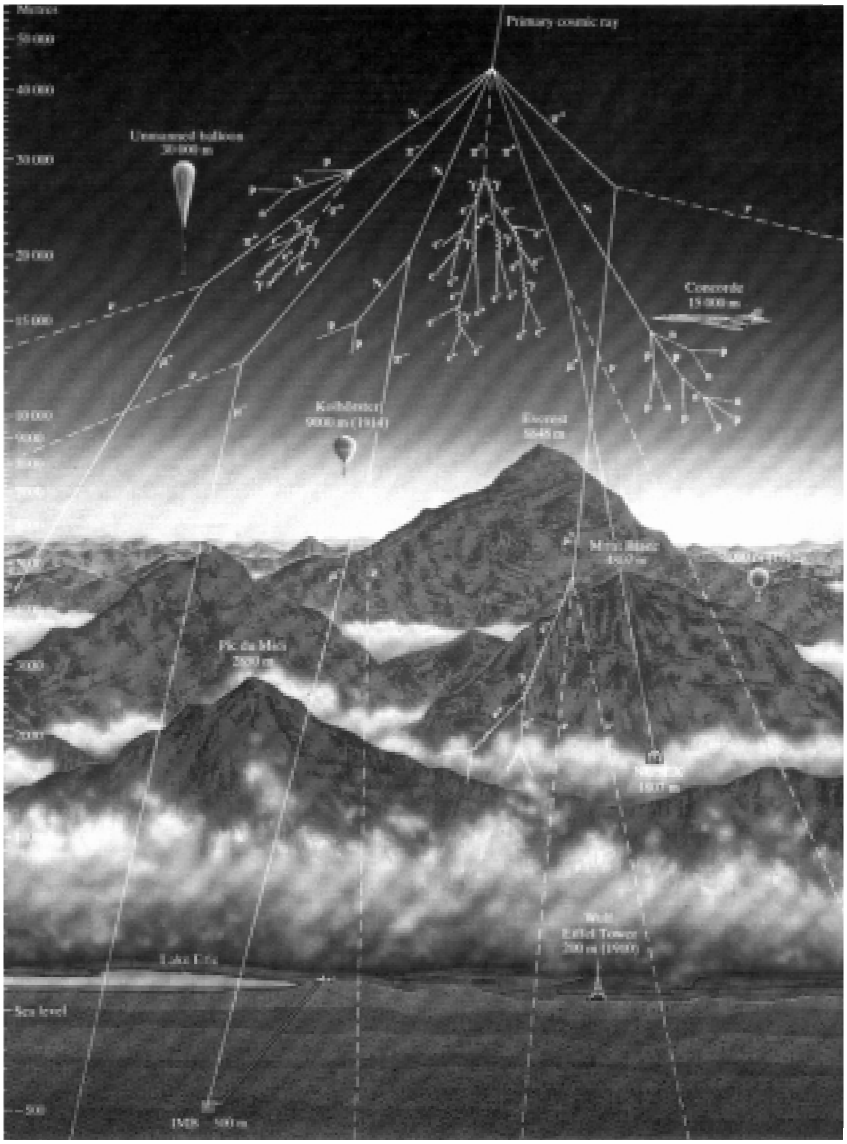
WALTA (WAshington Large area Time coincidence Array), University of Washington, Seattle, WA, USA.
ALTA (Alberta Large area Time coincidence Array), University of Alberta, Edmonton Alberta, Canada.
SALTA (Snowmass Area Large-scale Time coincidence Array), detectors installed in high schools in the Roaring Fork Valley area of Colorado.
CROP (the Cosmic Ray Observatory Project), University of Nebraska, Lincoln, NE, USA.
SCROD (School Cosmic Ray Outreach Detector), Northeastern University, Boston, MA, USA
CHICOS (California HIgh school Cosmic ray ObServatory), Caltech, UC/Irvine and Cal State/Northridge, California, USA.

A major NALTA goal is the education and recruitment of young scientists. Nebraska's Cosmic Ray Observatory Project has demonstrated the success of partnering universities with high school teachers and students—a few of the participants from CROP's first year in 2000 have decided to attend the University of Nebraska and major in physics, based on their summer and academic-year experiences working alongside university researchers.

The SALTA workshop in Snowmass brought together four high school teams from Colorado (Aspen, Basalt, Carbondale, Leadville) and one from Illinois (Wheaton North). A team consisted of a physics teacher plus three or four students with at least one year remaining before graduation. After bringing their equipment back home, the school teams embark on a series of experiments to exercise their detectors and practice making measurements in which statistical errors must be understood. For example, a vertical stack of detectors can be used to measure the small decrease of cosmic-ray rate with increasing barometric pressure. The higher the barometric pressure, the greater the density of the atmosphere between the earth and outer space, which means more cosmic rays are absorbed before reaching the earth's surface.

On this particular afternoon in Snowmass, the five high school teams were competing to see who could get their cosmic-ray telescope set up first, to start counting the coincidences signaling the passage of cosmic-ray muons through all four of their detectors. Tables, chairs, and cardboard boxes were gathered to create supports to stack the 2x2-foot scintillator panels on top of each other. Signal cables were connected to discriminators, and discriminator outputs were connected to logic units which were set to register "four-fold" coincidences of detector signals. Visual scalers, previously set to zero, started racking up counts.

MOST ENERGETIC Particles in the Universe



Development of Giant Cosmic Ray Shower in Earth's Atmosphere

The earth is constantly bombarded by subatomic particles from space. The energy spectrum of these particles reaches far higher than any terrestrial accelerator could hope to probe. When these high-energy cosmic rays reach earth, they interact with the atoms making up the earth's atmosphere. These high-energy interactions create an immense shower of particles, traveling in a cone centered on the direction that the original cosmic ray particle was traveling. At the highest energies, a single shower can be detected at the earth's surface over an area on the order of 100 square kilometers. If groups of cosmic rays to reach the, earth, the effective detection area of these multiple showers can be much greater. (Courtesy of NALTA)

"We're up and running!" declared Michelle Ernzen, a physics teacher from Lake County High School in Leadville, Colorado—the highest-elevation school in the United States.

Minutes later, Eric Livergood, an 11th grader from Wheaton North High School near Fermilab (elevation: about 600 feet above sea level), checked the scaler hooked to his school's detectors.

"Look!" Livergood exclaimed. "One ... two ... now five counts!"

Soon, all five detector stacks were counting cosmic rays. Kids and teachers stood back, took a breath, and slowly started comparing the counting rates measured by the different detector sets.

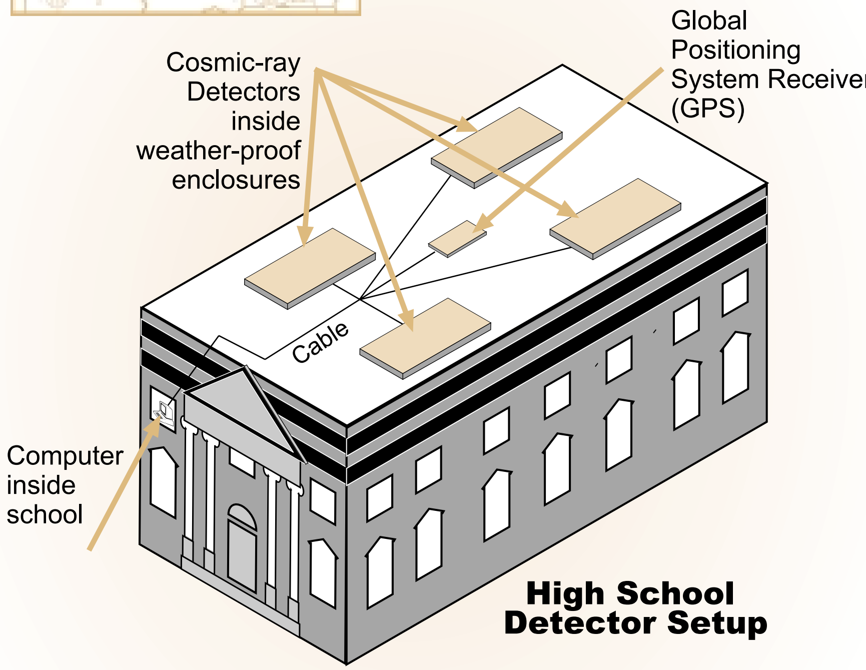
Heather Zorn, a physics graduate student from the University of Washington in Seattle, stood in the corner, quietly observing the flurry of activity. Then she sprang into action.

"Why don't we connect the five telescopes together," she said, "I mean count the coincidence of coincidences—then we'll have an extensive air shower array."

Signal cables were hastily strung from telescope to telescope, connected to a central logic unit and visual scaler, and the array of detectors started registering the passage of many particles through the room at the same time, the signature of a giant air shower initiated in the earth's atmosphere by a high-energy cosmic ray. But the event rate seemed much higher than what we observe at schools in Lincoln, Nebraska.

"Of course," Heather said. "The elevation is over 8,000 feet here in Snowmass—Lincoln is much closer to sea level."

Heather had demonstrated this same effect the previous weekend, when she participated in a reenactment of the famous 1912 balloon flight of Austrian physicist Victor Hess, who first measured the increase of the cosmic ray flux with altitude ("Balloon Flight Launches Cosmic Ray Education Project," *FERMINEWS*, vol. 24, no. 12, July 27, 2001).




NALTA Photo

SALTA students gluing photomultiplier tubes to scintillator panels at the Snowmass workshop.

The high school teams work from a more stable platform, mounting their weatherproof detectors on the school rooftop when they return with their apparatus. By spreading the detectors several meters apart in a horizontal plane, they create an array sensitive to extensive air showers. Several schools operating their own arrays a few miles apart, and synchronizing their data with a Global Positioning System (GPS) time stamp, can observe observe air showers created by the highest-energy primary cosmic rays known to man. Such cosmic particles (mainly protons, and the nuclei of light atoms) are hundreds of millions of times more energetic than the protons accelerated at Fermilab's Tevatron, and the air showers they create can spray billions of particles simultaneously over an entire city.

Physicists based in Aspen serve as local mentors for the SALTA schools in Colorado. Members of Fermilab's Graduate Student Association play the same role in Illinois, with Wheaton North a possible future hub for similar efforts near Fermilab. And within a year, the SALTA schools will use the World Wide Web to share their data and experiences with teachers and students in the other NALTA locations—just as physicists do in national and international collaborations.

SALTA is indebted to several several benefactors: a grant from an anonymous donor, the donation of a huge number of scintillation counters and photomultiplier tubes previously used by the Chicago Air Shower Array (CASA) in Utah, the long-term loan of electronic modules and oscilloscopes from Fermilab, and the participation of NALTA member physicists from the University of Alberta, Montana State University, University of Nebraska, and University of Washington. The NALTA physicists divided the Snowmass workshop days between classroom sessions and laboratory sessions, learning the physics of cosmic rays and particle detectors, then refurbishing and operating the recovered CASA detectors.

The equipment for these distributed cosmic-ray detectors might be second-hand, but there is no questioning their capability to perform "real science." High-school based detectors will not compete with measurements made by large-scale cosmic-ray experiments such as AGASA in Japan, HiRes in Utah, and the Pierre Auger Observatory in Argentina. But the NALTA arrays can make a unique contribution—and perhaps produce publishable physics results.

The excited voices of high school students at Snowmass, describing their first experiences with extraterrestrials, told us our field has a receptive audience and an energetic future. Stay tuned for news on our progress, and keep an eye out for cosmic ray researchers at a high school near you.

Particle Physics

MADE PAINLESS

A PARTICLE DIALOGUE

Hadrons are from Mars, Leptons are from Venus

by Bonnie Fleming
Lederman Fellow, MiniBooNE experiment

What are the first particles you learned about in physical science in 7th grade? Probably electrons, protons and neutrons.

The electron, the first subatomic particle to be observed, was discovered by J. J. Thompson in 1897. About 15 years later, the hydrogen's nucleus was identified as a proton; in another 15 years, the neutron was discovered. Since then, scientists have split open the proton and neutron to find a treasure chest of new particles. But electrons, protons and neutrons remain the basics of matter in the universe, the constituents of every atom.

What are these three foundation particles, how do we define them, how do they fit into the theory of elementary particle physics, the Standard Model—and how do we use them to explore the subatomic world? All particles that make up matter fit into two classes: hadrons and leptons. The word hadron comes from the Greek *hadros*, meaning "robust." Protons and neutrons, heavyweights in the Standard Model, are hadrons. The term lepton comes from the Greek *leptos*, meaning "thin." Electrons are 2,000 times lighter than protons. Appropriately, they are members of the lepton family. Hadrons and leptons, for all their differences, form a stable partnership in all forms of matter.

Lepto has been the word for the Greek penny (1/100th of a drachma) for more than a century. Moving from the drachma to the Euro has revitalized this tiny unit of Greek currency. Once, it equaled 1/400th of a U.S. penny and became obsolete; now it is approximately equal to a penny, and is back in circulation.

What are these particles made of? One way to find out is to split them open. A hadron has messy stuff inside, like an egg. Drop an egg on the counter, and yolk and white come spilling out of the cracked shell. Throw it against a wall and the yolk breaks open with egg innards flying everywhere. Throw one egg at another and get twice the impact, and twice the mess—all mixed

Fermilab's Tevatron, four miles in circumference, is a hadron collider. Collisions of protons and antiprotons produced the 1995 discovery of the top quark, viewed in an event from the CDF detector. The Stanford Linear Accelerator, three kilometers or about 1.8 miles long, is a lepton collider. Collisions of electrons and positrons produced the array of particles viewed in an event from the BaBar detector, producing a B and an anti-B meson, which decay into muons, pions and a kaon.

together. You might be better off just tapping the shell open with a spoon to see what's inside an egg.

Smashing hadrons

But this sort of gentle tapping does not work for hadrons. They are too small, and their shells are too tough, so we are forced to resort to the smash-it-open method. What we find inside looks different, too—it's not as simple as an egg.
At low energies, when we're just lobbing it at a target, the proton appears to be made of three quarks, called valence quarks; specifically, two up quarks and one down quark. But throw it harder and other particles can pop out as well.

Here at Fermilab, we collide protons at higher energies than anywhere else in the world.
This is a messy business, just like egg smashing, necessitating the huge CDF and DZero detectors. Protons traveling near the speed of light in the Tevatron are so energetic that, upon impact, they split apart into many pieces that themselves spray far out in all directions. At about four stories tall, each detector provides dense material to contain these particle products, so we can count them, measure them and see where they went flying.

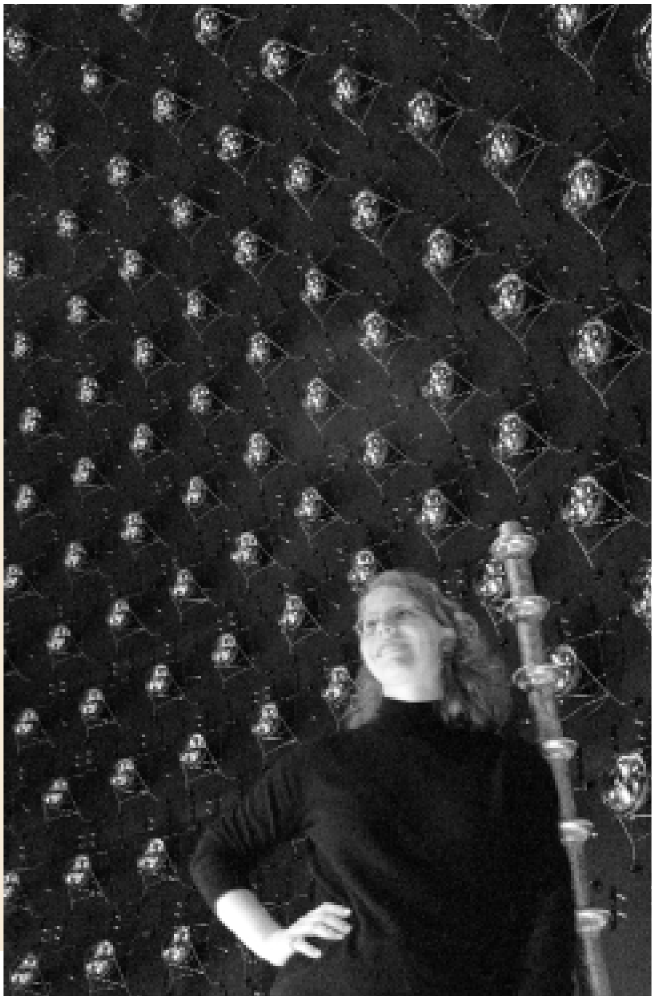


Photo by Reidar Hahn

The array of photomultiplier tubes in the MiniBooNE detector provides a backdrop for Lederman Fellow Bonnie Fleming.

Hadrons are from Mars, Leptons are from Venus

What do we see? At Tevatron energies, we find a whole particle sea in there, with quark and anti-quark pairs—the quark sea—in addition to the three valence quarks. The valence and sea quarks can also recombine to form other particles such as pions, a new type of hadron discovered in 1947. With two valence quarks instead of three, the pion is a different class of hadron from the proton and neutron. The lighter pion is known as a meson, from the Greek *mesos*, or middle. Hadrons with three quarks, such as protons, are known as baryons (Greek: *varys*, or heavy). There are a total of six quarks, paired in twos according to properties they have in common. All six can combine in many different ways to form groups of two (mesons) and groups of three (baryons).

There are many more particles in the hadron families than those I've mentioned, including perhaps, some we have not even discovered yet.

Loner Leptons

The lepton family is small by comparison, both in numbers and size, comprising only six elementary particles. Three leptons are electrically charged: the electron, the heavier muon, and the still heavier tau. Three are electrically neutral and unusually small: the electron neutrino, the muon neutrino and the tau neutrino. These neutrinos have properties in common with their respective charged lepton siblings and are therefore paired with them. Like the quarks, leptons appear to be structureless, fundamental particles, the building blocks of matter. Unlike the clingy quarks, which appear only in groups as mesons or baryons, the leptons are real individualists, preferring to be on their own.

Since leptons are structureless (as far as we know), they are a good tool for probing hadrons. They allow us to crack the shell and see what's inside. Colliding a lepton and a hadron is a lot like firing a tiny bullet at an egg. A small enough bullet may not even crack the whole egg open but rather pass right through leaving a little hole and taking a little bit of the inside. Fire lots of tiny bullets at the egg and you can map out the entire inside. In this way, leptons have proven to be a very precise way to find out what's inside hadrons.

So far we've seen that hadrons are bigger, messier and more complicated than leptons. They are also more talkative. In the Standard Model, particles interact by exchanging special particles that carry forces. The electromagnetic force is transferred by exchange of the photon. The strong force exchanger is the gluon; the weak force exchangers are the W and Z particles. Neutrinos, the uncharged leptons, are particularly shy. They will talk with other particles only via the weak force. The charged leptons are a little more outgoing and will interact via the weak force or the electromagnetic force. Hadrons are gregarious by comparison, willing to interact via any of the three Standard Model forces—weak, electromagnetic or strong.

Hadrons and leptons look different, behave differently and, in general, have very different personalities. But their ability to work together has stood the test of time in forming the stable constituents of every atom in the universe as we know it. So far.

CALENDAR

Website for Fermilab events: http://www.fnal.gov/faw/events.html

FERMILAB ARTS SERIES PRESENTS: HALLEY'S COMET FEATURING JOHN AMOS – FEBRUARY 16, 2002

Tickets: $24 ($12 ages 18 and under) Free Tickets for Police/Fire/Military & Emergency Personnel

"A funny and touching journey through 76 years of the American experience."

Daily News, New York

Special Guests - Ministers of Life Gospel Choir, New Covenant Life Church, Chicago
Actor/Playwright John Amos (nominated for an Emmy as the adult Kunta Kinte in "Roots") has been on a world tour with Halley's Comet for the past ten years. Amos is currently appearing in NBC's hit-series "The West Wing," where he portrays Admiral Percy Fitzwallace, Chairman of the Joint Chiefs of Staff in a recurring role. As a special request by Mr. Amos, free tickets will be available for all police, fire, military and emergency personnel. Please call our box office at 630/840.ARTS for information.

This remarkable tour de force is the funny and moving story of an 87 year old man who shares the memories of a lifetime with the famous comet he saw 76 years earlier as an 11 year old boy. As special guests, the Ministers of Life Choir from Chicago's New Covenant Life Church will appear. This award-winning choir has performed on television and radio.

To purchase tickets, or for further information or telephone reservations, call 630-840-ARTS weekdays between 9 a.m. and 4 p.m. Phone reservations are held for five working days, but will be released for sale if not paid for within that time. Will-Call tickets may be picked up, or available tickets purchased, at the lobby box office on the night of the performance beginning at 7 p.m.

Please note that at this time Wilson Hall is not open to the public during business hours. When coming to this lecture, only the Pine Street entrance to Fermilab will be open.

For more information, check the Web at www.fnal.gov/culture.

CAR- AND VANPOOL

Groups are forming now. Check the webpage at www.fnal.gov/faw/vanpool/

BROWN BAG SEMINARS: PHYSICS FOR EVERYONE

Each month, usually on the first Tuesday, Fermilab presents a seminar to make particle physics accessible for everyone. The seminars are held from 12 Noon to 1 p.m., in the 1-West conference room of Wilson Hall. Coming events: **Tues., Feb. 5:** Matter and Anti-Matter, Bob Tschirhart. **Tues., Mar. 5:** Many Dimensions in Particle Theory, Joe Lykken. **Tues., April 2:** Higgs Bosons, Marcela Carena. **Tues., May 7:** Future Accelerators, Dave Finley.

NALWO

The National Accelerator Laboratory Women's Organization cordially invites Fermilab women, guests, and visitors to a Russian cooking demonstration/lunch at the Users Center - Chez Leon prepared by Tatiana Terentiev and Natalia Kouropatkina, Friday, February 8, 2002 from 10:30 a.m. until 1:00 p.m. Please join us for casual conversation and light lunch. RSVP to the Housing Office 630/840-3082.

ONGOING NALWO

Free English classes in the Users' Center for FNAL guests, visitors and their spouses. The schedule is: Monday and Friday, 9:30 a.m. - 11:00 a.m. Separate classes for both beginners and advanced students.

MILESTONES

NAMED

As 2001 Fellows of the American Physical Society:

- Carl Albright, for his contributions to the physics of electroweak interactions, particularly weak neutral currents, quark mixing, and neutrino masses and mixing;
- Stephen Geer, for his leadership in the US effort towards a neutrino factory based on a muon storage ring;
- Byron Lundberg, for his leadership of the experiment which gave the first direct evidence for the tau neutrino;
- Regina Rameika, for her crucial role in establishing the first direct evidence for the tau neutrino;
- Randal Ruchti, for providing forefront directed research experiences as a co-founder of QuarkNet for high school teachers in particle physics;
- Paul Tipton, for playing a lead role in the discovery and study of the top quark, and for his part in the construction of the SVX detector used in that discovery;
- Philip Michael Tuts, in recognition of his contributions to elementary particles as a leader in the CUSB and DZero collaborations in designing, implementation of experiments and analysis of important data, including efforts that directly resulted in observation of the Upsilon.

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, February 6

Slow Baked Salmon Fillet with Herbed Olive Oil

Roasted Winter Vegetables

Blueberry Bread Pudding with Maple Whiskey Sauce

Dinner
Thursday, February 7

Black Bean Soup

Swordfish Brochette

Risotto with Zucchini, Corn and Red Pepper

Bourbon Pecan Cake with Browned Butter Glaze

Lunch
Wednesday, February 13

Raspberry Chicken

Wild Rice With Green Onions, Peapods and Mushrooms

Poached Pears with Chocolate Sauce

Dinner
Thursday, February 14

Red Pepper Soup

Medallions of Lobster with Tomato Champagne Butter Sauce

Spicy Noodles with Fresh Vegetables and Ginger

Lover's Salad

Heart Shortcake with Strawberries

FERMI NEWS

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The deadline for the Friday, February 15, 2002, issue is Tuesday, February 5, 2002. Please send classified ads and story ideas by mail to the Public Affairs Office, MS 206, Fermilab, P.O. Box 500, Batavia, IL 60510, or by e-mail to ferminews@fnal.gov. Letters from readers are welcome. Please include your name and daytime phone number.

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FERMINEWS MCMLXXVII

CLASSIFIEDS

FOR SALE

■ '98 Jeep Grand Cherokee Ltd., Silver, 4WD, 6 cyl, 56K miles. Ac, ps, pb, pl, pw, pds, psunroof, AM/FM/cassette/CD, tint, alloy, luggage rack, and more! $14,500. 630-579-4036 Tamara or x8313 Sergey, los@fnal.gov

■ '97 Pontiac Grand Prix GT SE, 4 door, every option except leather interior. 62K miles. 30K miles left on warranty. Excellent condition, white exterior w/gold accents, gray cloth interior, $12,500. Call Ed, work x6300, home 630-665-6674, dijak@fnal.gov

■ '91 Mazda Protege DX, 5 speed, 4 Dr., AC, PS, AM/FM/Cassette 140K miles, new tires, clutch, muffler and recent tune up. Asking $1,000 o.b.o. See more at: http://www.hep.upenn.edu/~cchen23/mazda/ email: cchen23@fnal.gov or call x3163, 393-2110(H).

■ '89 Toyota Celica GT Liftback, 2-door, 5-speed stick, cruise control, all power, excellent engine & gas mileage. Some rust. Must sell at the end of the month for cause of departure. 119K miles, $1,000 o.b.o.! tourneur@fnal.gov or X6849

■ PDA - Handspring Visor Platinum. Palm OS, 8MB RAM, 33MHz processor, expansion port. With USB synch cradle, cover, case, screen protectors, all software and packaging. Includes Date Book, Address Book, To Do List, Memo Pad, Fast Lookup, Advanced Calculator, World clock, Handwriting software, E-Mail, Expense, and more. $175. Matt 630-674-7448.

■ Viking 1+ sewing machine with embroidery unit. 8 years old, excellent condition. Includes 4 embroidery cards (#1, #4 - Holidays, +12 - Flowers, card of crests and shields from embroidery library): stitch cassettes A, B, D, F, L: extra feet - ruffler, walking foot, 1/4″ piecing foot, bias-binder application foot, open-toe applique foot, edge-stitching foot, piping foot: instruction manuals: binder of embroidery designs available from Viking. $1,400. Contact Liz Buckley-Geer x8650, buckley@fnal.gov.

■ Twin size couch that opens to a bed, floral pattern, asking $75. Call Ed, 630-879-9404.

■ Furniture refinishing and restoration. Pick-up and delivery services available. Call 815-695-5460 or x3762.

■ Custom wheels/tires. KMC Evolution 17″x7″ Universal 5-lug wheels, with NITTO NT450 225/45ZR17 tires. Mounted / balanced, less than 10K miles on tires, stored winters, lug nuts and locks included, $1,250. Call Ed, work x6300, home 630-665-6674, dijak@fnal.gov

EARLY RISERS?

■ Looking for fellow early risers to walk the Fox River bike path Sunday mornings. Call Michelle x8062.

WANTED

■ Coed Volleyball league is looking for additional female players. Games are Monday evenings at 6:30 and 7:30 p.m. Fermilab gym membership is required. Please contact Elizabeth Gallas, eggs@fnal.gov.

LOOKING TO RIDE SHARE

■ We're looking for riders to join our vanpool from the West Chicago or Winfield Metra station. The van will leave the station at 7:45 a.m. for Fermilab. It will leave for the station at 4:45 p.m. Van riders don't need to ride the train, but must meet the van at the station or en route to the lab. The cost is approximately $40/month (+ train ticket if applicable). Contact bgreen@fnal.gov or riordan@fnal.gov if interested.

■ For additional ride share opportunities, see the Car- and Vanpool Website at www.fnal.gov/faw/vanpool/ and post your own message.

SPECIAL OFFER FOR FERMILAB FROM THE PRODUCERS OF "COPENHAGEN:"

Save $20 when you buy two tickets

See Copenhagen at Chicago's Shubert Theater on Sunday, Feb 10 at 7:30, Tuesday, Feb 12 at 7:30 or Wednesday, Feb 13 at 7:30 and receive $20 off a pair of tickets. To purchase tickets at this special price call 312-902-1400, visit any Broadway In Chicago box office (22 W. Monroe, 24 W. Randolph or 151 W. Randolph in downtown Chicago) or go on line at www.ticketmaster.com. Use the code "MATOM" when ordering.

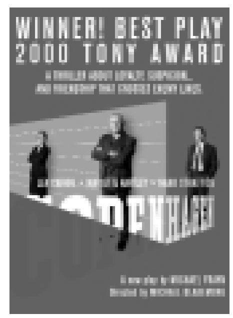
Please note that this discount is not applicable on previously purchased tickets or in conjunction with any other offer. Tickets are subject to availability and all normal handling fees will apply.

The show runs Feb. 7-24. Visit the website at www.copenhagenontour.com

"COPENHAGEN" SYMPOSIUM

February 16, 3 to 5 p.m.discussion with panel of professors and actors of the production. At the Oriental Institute Museum, Auditorium, 115 E. 58th St., Chicago. Free admission, open to anyone.

www.fnal.gov/pub/news02/copenhagen.html



CORRECTION

In "A Cryostat on the Edge" (*FERMINEWS*, vol. 25, no. 1, Jan. 18, 2002, pg. 6), the person working on the cryostat in the Soudan clean room is Jeff Duncan, not Rich Schmitt as identified in the caption.

LAB NOTES

URA SCHOLARSHIPS REQUIRE SAT TEST SCORES

Universities Research Association (URA) awards a number of scholarships to children of regular, full-time Fermilab employees. URA scholarships are awarded on the basis of SAT (Scholastic Aptitude Test) scores. Scholarship candidates must be high school seniors who will begin a four year college degree program next fall. The maximum amount of the scholarship is $3,500 for tuition and fees, and is renewable for four years for students in good academic standing. Applications are available January 1 through March 1. Scholarships will be awarded in early April. Questions about the program may be directed to Jeannelle Smith of Human Resources, Mail Station 124, extension 4367.

RECREATION OFFICE

Adult Outing-Spirit of Chicago Island Fever Cruise, March 16; Muscle Toning, Tai Chi, & Pilates Classes; Climb a Mountain Exercise Program; Discount Movie Ticket Sales; Entertainment Book Sales. Check the Recreation web page http://fnalpubs.fnal.gov/benedept/recreation/recreation.html

HOUSING ASSIGNMENTS – SUMMER 2002

The Fermilab Housing Office is now taking requests from Users for houses, apartments, and dormitory rooms for the Summer of 2002. Since there will be a large influx of experimenters during the summer, and requests are anticipated to be in excess of our available facilities, you are urged to submit your request for reservations to the Housing Office by March 1, 2002. Requests can be made for any period and need not commence on any particular date. For further information, please contact the Housing Office at: Telephone: 630 840-3777 Fax: 630-840-2823 Email:housing@fnal.gov

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

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