FERMI NEWS

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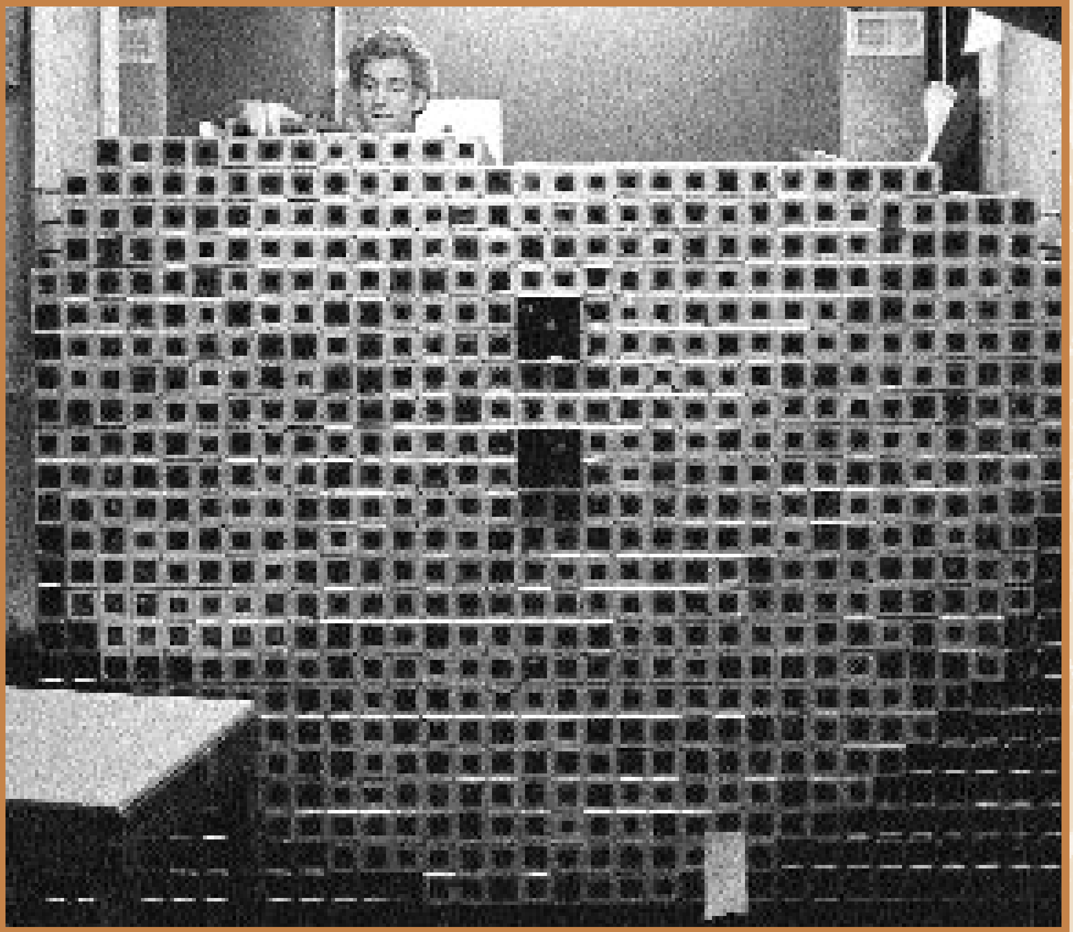

Fermilab Photo

SPECIAL ISSUE

FIXED TARGET

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Number 12

INSIDE:

Idée Fixe ~or~ 101 *Things You Can Do With a Proton Beam*

"It is an ever fixèd mark…"

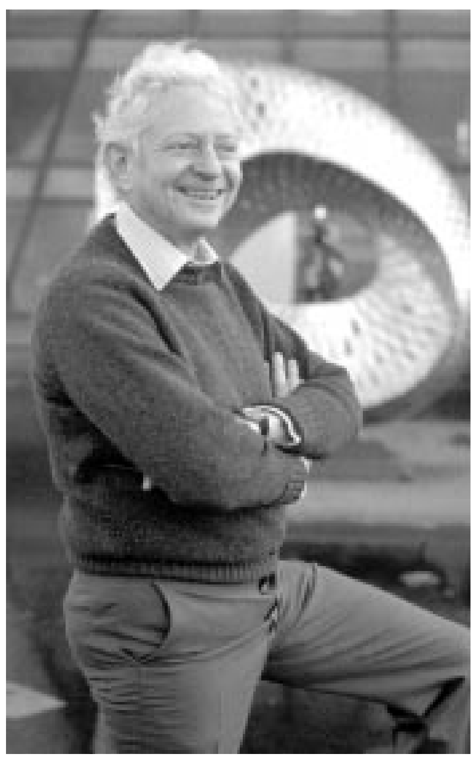
—William Shakespeare, *Sonnet CXVI*

by Judy Jackson

First of all, it has nothing to do with "broke." The "fixed" in "fixed-target experiment" means stationary, in one place, rooted to the spot. The opposite of the moving targets—speeding protons smacking speeding antiprotons, for example—of "colliding beam experiments."

To make a fixed-target experiment, you need three things: a beam of particles, a target and a detector to see what happens after you hit the target with the particles. (Strictly speaking, as fixed-target maven Leon Lederman points out, you also need a fourth thing: the funding to build the other three.)

Perhaps the most famous fixed-target experiment of all time was the one that started the whole gorgeous enterprise of subatomic physics, back in 1910. That's when Ernest Rutherford and his students sent alpha particles from a lump of radium (the particle beam) to a sheet of gold foil (the target) surrounded by screens of zinc sulfide (the detector). When alpha particles (helium atoms minus their electrons) passed through the gold foil and struck the screens, the collisions with zinc sulfide molecules made flashes that Rutherford's students, sitting for hours in the dark, could see. When—famously, astonishingly—some of the alpha particles bounced back from the gold foil target, Rutherford had discovered the atomic nucleus. Using a fixed-target experiment.

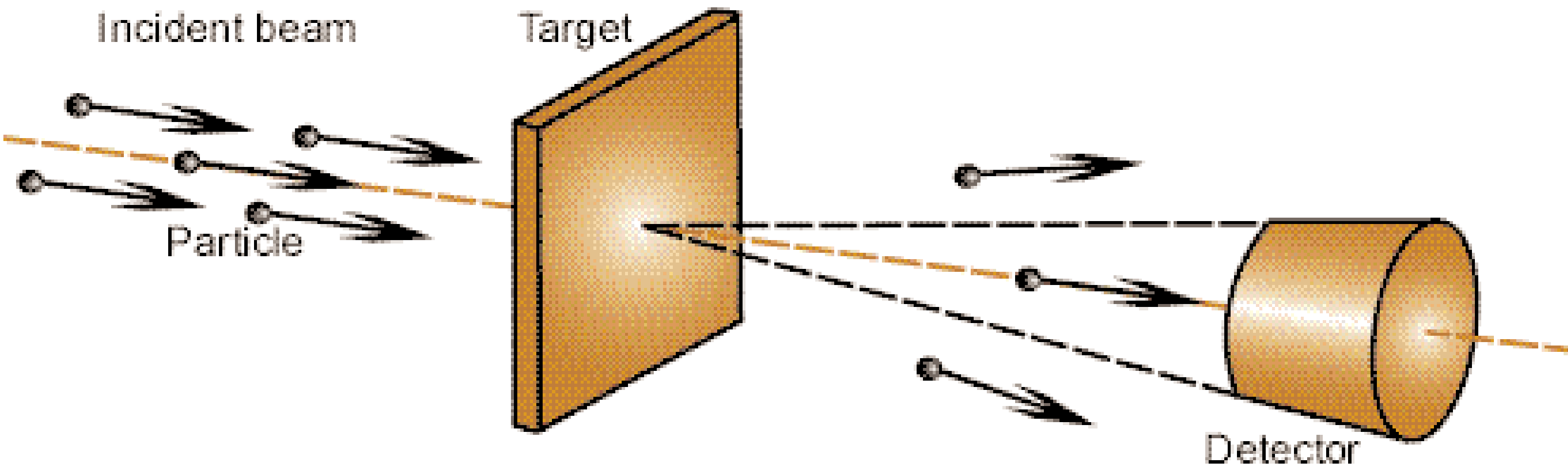


Leon Lederman

From there, it took a mere 70-odd years and few thousand fixed-target experiments to create the Standard Model of Elementary Particles. (To be fair, a number of theorists and one or two collider experiments also helped, here and there.)

All the fixed-target experiments that have followed Grandaddy Rutherford's first foray into the atom are really just more sophisticated—much more sophisticated—versions of that

Cover Photo: Bruce Winstein works not-quite-behind-the-scenes on the lead-glass block array for experiment E731 ("A Precision Measurement of the CP Violation Parameter (ε'/ε) in the Neutral Kaon System") at the Meson Center in 1984. E731 was the predecessor to the KTeV experiment which announced direct observations of CP Violation in neutral kaons in 1998. The connection continues with the proposed KaMI (Kaons at the Main Injector) experiment, which would use the KTeV detector, for Fermilab's next generation of fixed target experiments.



first simple model: particle beam, target, detector. (What about the fourth element, funding? Did Cambridge University fund Rutherford's experiment? How much did it cost? One imagines the funding committee for the Cavendish Laboratory: "Do you have to use gold foil? Couldn't you use copper? How about balsa wood?")

The fixed-target experiments that followed made extraordinary improvements and refinements in each of the three elements.

"Rutherford's students had to sit around in the dark looking for particle events," observed Fermilab fixed-target physicists and Associate Director Mike Shaevitz. "Now we have computers that sit around in the dark for us. But it's the same principle."

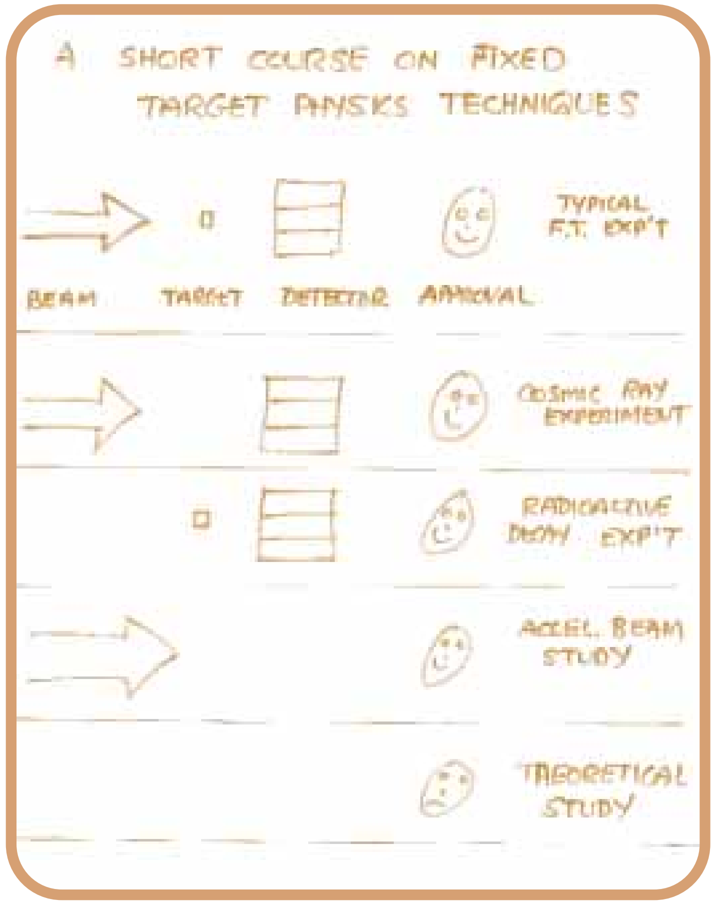
The principle: Particles in a beam collide with particles in a target, creating many secondary particles. The secondary particles may be objects of study in themselves, or experimenters may used them as probes of still other particles and forces.

Over the years, physicists learned to use accelerators to make particle beams millions of times more powerful and vastly more intense than Rutherford's alpha particles. They learned to choose targets of different materials and different sizes and shapes to suit the objects of their interest. They built detectors of dazzling intricacy, scope and precision. They programmed computers to sit in the dark and watch.

By varying the beam energy and changing the target, Fermilab physicists learned to take a beam of protons from the Tevatron and create an entire menu of secondary beams. Using magnetic fields, absorbers and other clever tricks to sweep away the extraneous particles produced in collisions at the target, they created an array of designer beams for their experiments:

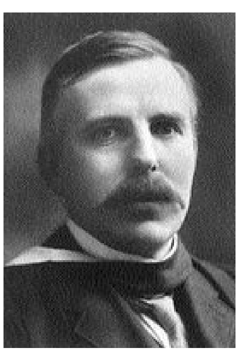
- **Kaons**
- **Pions**
- **Muons**
- **Neutrons**
- **Photons**
- **Electrons**
- **Neutrinos**
- **And their antiparticles**

"It was obvious that if a device could accelerate particles and even generate an intense stream of very energetic particles, it would be



Transparencies courtesy Leon Lederman

In his presentation for the Fermilab Fixed Target Symposium, Leon Lederman rings out the old and rings in the new (left); and depicts the process of fixed target experimentation compared to other high-energy physics undertakings.



Ernest Rutherford

Some metaphors for fixed-target experiments:

If we think of collider experiments as power tools for a broad range of discoveries, we can think of fixed-target experiments as a set of scalpels to dissect particular particles and processes. The machine tool versus the surgeon's knife.

Fermilab physicist and Associate Director Steve Holmes compares a fixed-target experiment to a pinata at a birthday party. The pinata hangs there, and kids whack it with a baseball bat until goodies fall out. Perhaps this is more the point of view of an accelerator builder (the whacker) than of the experimentalists, who might feel they play a more active role than merely waiting to see what falls out. But you get the idea.

Fixed-target experiments often explore the behavior of secondary particles created by proton beams. Fermilab's KTeV, for example, made beams of kaons and studied their decay, to confirm the asymmetry between matter and antimatter. MINOS will create a beam of muon neutrinos and scrutinize them for signs of oscillation to tau neutrinos, as evidence for neutrino mass.

Alternatively, experimenters may create beams of secondary particles to use as probes for exploring still other phenomena. NuTeV used a beam of neutrinos to study the properties of protons. FOCUS used a photon beam to study charm quarks.

Beginning with Rutherford's discovery of the nucleus, which started it all, fixed-target experiments have progressively illuminated the subatomic world of quarks and leptons, and the forces at play among them. In a particle-physics world now dominated by the high-energy of colliders, fixed-target experiments will continue to create unique opportunities for insight into the fundamental nature of matter. ☐

PHYSICS Achievements of the Fixed Target ERA

Photo by Reidar Hahn

The fixed target celebration on June 2 brought together physicists that have had strong connections to Fermilab's fixed target program: Former director Leon Lederman (right), theorist Chris Quigg (center) and Satoshi Ozaki, Associate Director at Brookhaven.

Atoms or systems into ruin hurl'd,
And now a bubble burst, and now a world.

—Alexander Pope, *Essay on Man*

by Kurt Riesselmann

In the 1970s, uncertainties were the only certainties at Fermilab and in the field of particle physics.

"There were periods of immense confusion," Chris Quigg remembers of those early days in Fermilab's theory group. "Theoretical models were made and discarded every few weeks."

Fermilab's fixed target experiments began clearing the daze. Starting in 1972 the experiments helped, step by step, to establish our present knowledge of the smallest particles and their interactions, the structure of proton, the role of particle interactions in the evolution of the universe. They provided guidance for theorists to find the right description, unearthing the underlying symmetries. Their findings have been essential in creating the Standard Model of particle physics.

The Early Days

Particle physicists at Fermilab obtained some of their first results operating a fixed target experiment with a 30-inch bubble chamber as their detector. Charged particles leave a track when traveling across a bubble chamber, similar to an airplane contrail leaving a line in the sky.

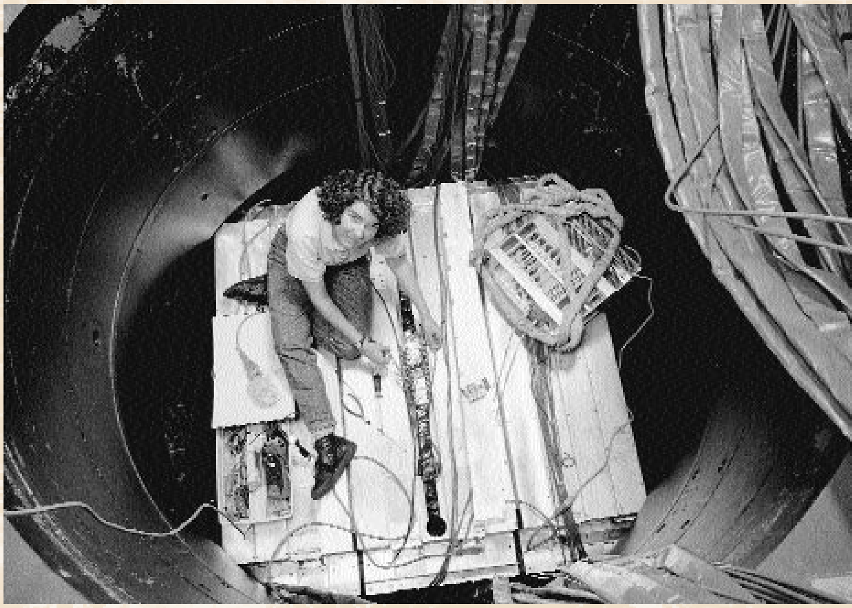
"Back then the bubble chamber pictures, showing many tracks, were new to everybody and quite striking. [Richard] Feynman carried around the photographs, showing them to everybody," Quigg recalls.

"In 1972, the new accelerator was not yet performing very well. But it was just right for the bubble chamber," says Ernie Malamud, who was among the lab's first 100 employees. "Ten particles were enough for a picture."

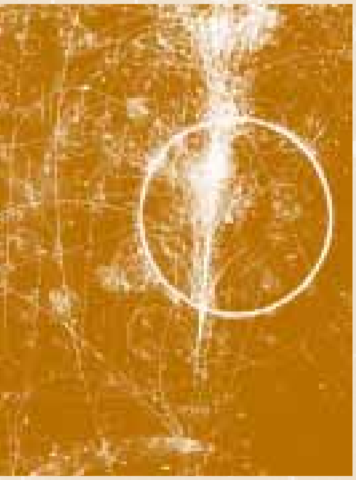
Taking tens of thousands of pictures, Fermilab's bubble chamber produced clearer results than any other experiment at that time.

The next-generation detector, a 15-foot bubble chamber, confirmed the existence of neutral current scattering, shortly after Europe's CERN laboratory had recorded the first evidence. Scientists observed that protons sitting in a neutrino beam occasionally received a kick, without any charged particle emerging from the event. Some sort of neutral interaction was taking place. The number of events agreed with the electroweak model, a theoretical framework suggested by Sheldon Glashow, Stephen Weinberg and Abdus Salam, who later won the Nobel Prize. It took another ten years until experimenters discovered the particle mediating the neutral current interaction, the Z boson, at CERN.

The seventies were the heydays of discovering new particles. Many fixed-target experiments aimed at identifying and analyzing hyperons, bound quark states containing at least one strange quark. Similar to Mendeleev's grouping of chemical elements in a systematic table, particle physicists tried to identify the underlying pattern of the many quark bound states they found, a major key in establishing the Standard Model. Fermilab's hyperon experiment E8 made significant contributions. It measured the magnetic moments of hyperons, extensively testing the quark model. Looking at today's particle data tables one finds that many composite particles were discovered, and their properties best measured, at the Tevatron fixed target program.



Heidi Schellman, now a professor at Northwestern University, worked on the E665 experiment, shown here in 1990. “Recycling has been a theme of the fixed target program,” she told the audience at the Fixed Target Symposium on June 2. “Equipment from one experiment was re-used in another.” The strong permanent magnet used by E665 came from CERN, and physicists returned it to CERN after completing the experiment.



Bubble chamber tracks, 1978

Dissecting the proton

Using neutrino beams, physicists at Fermilab have studied the structure of the proton at ever-smaller scales. Some of Fermilab’s earliest results in this area helped to identify quantum chromodynamics (QCD) as the correct theory of strong interactions, the force combining quarks into little packages. Physicists discovered what is called ‘scaling violation,’ a specific energy dependence of the neutrino scattering off a quark inside the proton. The simple parton model, viewing the proton as a bag with non-interacting quarks inside, turned out to be wrong. Instead, QCD provided the correct description of the scattering processes, including scaling violation.

Subsequent fixed target investigations at Fermilab, SLAC and CERN have greatly contributed to the understanding of the ‘virtual sea’ of quarks and gluons inside the proton. Together with data obtained at Germany’s DESY laboratory, where an electron-proton collider is used to study the proton’s content, this knowledge of the proton structure is essential for making measurements at the future Large Hadron Collider (LHC) being built at CERN.

Charming events

The simultaneous discovery of the charm quark, the fourth kind of quark, at SLAC’s electron-positron collider and a fixed target experiment at Brookhaven in 1974 was a milestone. It led to a wide acceptance of the picture of the quark-lepton substructure of matter. Fermilab, of course, wanted to participate in exploring the properties of charmed particles.

“Even some well-known physicists thought that this kind of physics could only be done with electron-positron colliders, which presumably allow for measurements with much less background,” recalls Mike Witherell, former spokesman of E691 and now director of Fermilab. “Not everybody on the program committee was convinced in advance that E691 would work.”

Fermilab’s set of extremely influential experiments on charm photoproduction, E516, E691 and E791, firmly established the fixed-target program as a first-class source for data on charm quark physics.

“You often find a chain of experiments that over time morphed into some of the most powerful experiments,” says experimentalist Chuck Brown, seemingly lifting Fermilab’s secret of success.

Fermilab contributed to unraveling the secrets of the production mechanisms behind charmed particles in a fixed target environment, which is completely different from producing them in electron-positron experiments.

“Probably more than half the information we currently have on charm quarks comes from fixed target experiments, yielding beautiful lifetime measurements and branching fractions.
The Tevatron fixed target experiments had overwhelming statistical power because they evolved over a long period of time,” notes Quigg. “Cornell’s electron-positron collider (CESR) and its CLEO detector is another source of high-quality information.”

Fermilab’s experiment E516 was the first experiment using a full solid angle spectrometer. It recorded particles coming out of a collision and flying off in all directions. Previous experiments used bubble chambers which have limited statistical power because data analysis is slow. Or they used small angle spectrometers, only recording particles flying in certain directions.

“Once you study charm quark physics you have multi-particle interactions,” states Tom Nash, a member of E516. “You need to electronically register all particles produced. Then processing this huge amount of data becomes the issue.”

E516 was the first experiment to use parallel computing with commercial microprocessors. Computer Farms with more than 50 microprocessors were built.

The follow-up E691 successfully implemented another leap in technology: the use of silicon vertex detectors, which were indispensable encouragement for the future use of hadron beams to do these kinds of measurements.

THE DISCOVERY OF THE BOTTOM QUARK

In 1977, a whole new field of research started at Fermilab with the discovery of the bottom quark, the fifth quark of the standard model. Analyzing data from fixed-target proton-proton collisions, the relative frequency of producing muon-antimuon pairs showed an anomalous peak at about 9.7 GeV. Physicists had discovered the upsilon particle. Further investigation proved this particle to be a bottom quark-antiquark pair.

“Leon Lederman came to Fermilab as the spokesman of E70 and then E288. His proposal for E288 was the shortest I have ever seen,” laughs Brown. “It was one page long, and basically said: ‘We hope to discover particles.’”

The HyperCP experiment used optical fibers in their 64-layer sampling calorimeter. 256 fibers guide light from the calorimeter to one cell containing a photomultiplier. Casey Durandet, now assistant professor at the Maricopa County College District in Phoenix, Arizona worked on the installation of the fibers in 1996.

Instead of the W boson, which Lederman and his collaborators expected to find, they discovered the upsilon.

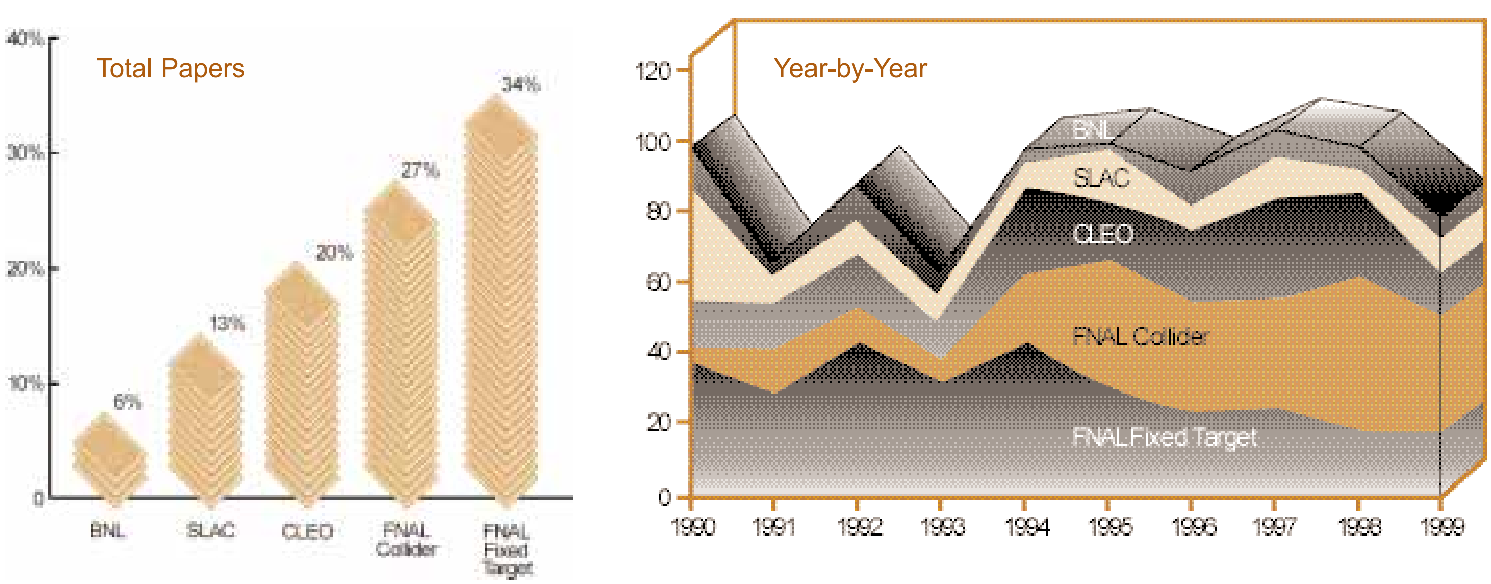
The bottom quark is today the focus of extensive studies around the world. Its properties may hold the key to many physics questions that cannot be answered in the framework of the standard model.

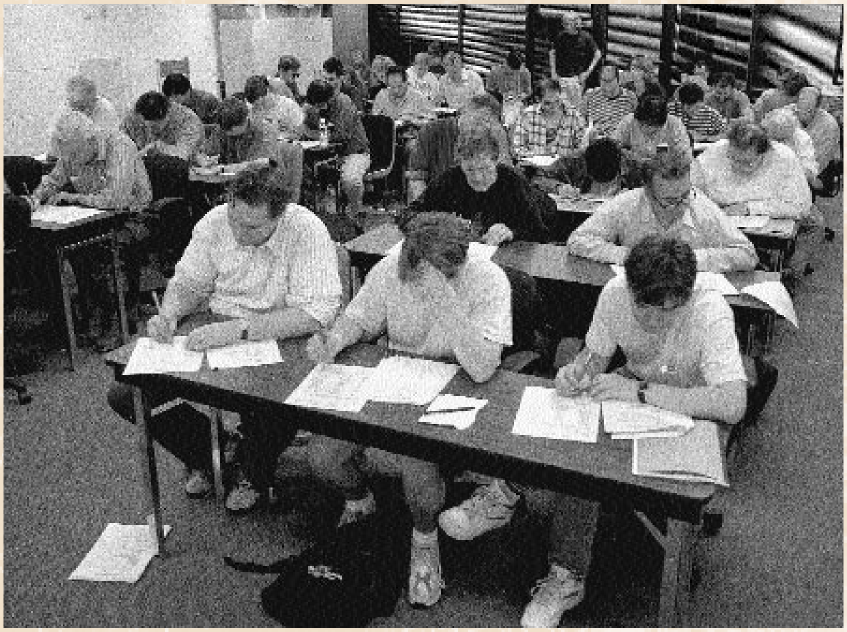
THE MATTER-ANTIMATTER ASYMMETRY

Particle physicists around the world have been able to produce antiparticles for many decades. And they think that a lot of antimatter was present at the beginning of the universe. But where did it all go?

Experiments conducted in the 60s showed that particles and antiparticles do not behave in the same way. There is a slight change in the outcome

U.S. Experimental HEP Publications 1990 to 1999





Members of the KTeV experiment had a special study session in 1996 when they all gathered to take a Fermilab Safety Test.

of some physics processes when replacing all particles by their antiparticles. Physicists speak of CP violation.

So far, measurements of kaon decays offer the only evidence for this matter-antimatter asymmetry. Studying these tiny effects requires very sophisticated fixed-target experiments.

“CERN’s NA31/NA48 and Fermilab’s E731/KTeV experiments are some of the most beautiful experiments we have in particle physics,” Quigg credits his experimental colleagues. “People have evolved the technique over time, built in ways of controlling their systematic errors, understood the details of their analysis.”

It is a challenge to measure an effect that is only of the order of one per thousand. Then, measuring this effect to a precision of a tenth of one thousandth is a really big challenge. CERN and Fermilab have achieved this goal, a very important result.

“Theorists will need much more precise calculations to match this,” says Quigg realizing that it’s the theorists’ turn to get as much as possible out of these results. Indeed, the latest experimental results eliminated the possibility of a so-called superweak model to explain the matter abundance in our universe. It is clear, however, that nature must have provided for an extra source of CP violation to create a universe that seems to be made almost entirely of matter, with very little antimatter present.

“We know that CP violation in the standard model of particle interactions is not sufficient to explain the matter excess in our universe. Whether we need some sort of transcription of the standard model or something completely different, we don’t know”, explains Quigg. “One of the things you hope to find in the next generation of experiments, as you begin to pin things down more, is some systematic deviation from the standard model even for kaon and bottom quark physics.”

Answers of the future

The ongoing analysis of data taken during the last phase of the Tevatron fixed target program will hopefully yield yet another first-time observation of a particle. The elusive tau neutrino has never been directly observed. So far it has always been seen indirectly in form of missing energy: An undetected particle carries away some of the total energy entering a collision. The direct observation of the tau neutrino, however, requires identifying the interaction of a tau neutrino with a target nucleus, producing a very short-lived tau particle, a heavy relative of the electron and muon. Physicists of the DoNUT collaboration expect to have recorded enough events. Sifting through the data, however, is not yet complete.

“We know that the standard model is not the final answer,” summarizes Quigg. “We want to get to finding the cracks, understanding the electroweak symmetry breaking. The next ten years will be very exciting years for experimental particle physics. A lot of things have the potential to start popping out on us, especially supersymmetry or topcolor. In addition, the wonderful experimental results indicating that neutrinos have a mass and oscillate are tied to the problem of the masses for quarks and leptons. Together with electroweak symmetry breaking, this is the next big problem to be solved.” □

The commemorative catalog of Fermilab’s fixed target program with the Tevatron (1983-2000), edited by Jeff Appel, Chuck Brown, Peter Cooper and Herman White, can be found at http://conferences.fnal.gov/tevft/book/.

The DONUT collaboration is still analyzing the data it took in 1997. Vittorio Paolone and his collaborators hope to directly observe tau neutrino events by using emulsion targets.

EDUCATION: Right on TARGET

by Kurt Riesselmann

They come from Aachen and Utsunomiya, from Ball State and Yale.

Graduate students from near and far make a pilgrimage to Fermilab to learn the trade of being a high-energy physicist. After years of long working days, writing thousands of lines of computing code, drinking hundreds of cups of coffee and working too many night shifts, they are ready for their recognition:

Doctor of Philosophy (Ph.D.).

These students are not out for quick riches–at least at the early stages of their career. They know, of course, that their knowledge and skills are highly marketable in today's technology-driven society. After all, scientists at CERN, one of the top high-energy physics facilities in the world, invented the World Wide Web.

Gone are the days when physicists ponder alone the secrets of nature. Today's high-energy physicists must be global team players, with collaborations sometimes including more than 300 international scientists. Designing, constructing and operating physics equipment consisting of millions of wires and components requires careful planning and management. Deadlines, a word frowned upon by many physicists, have become the norm, as competition has increased for recognition and funding. Together with data analysis and problem-oriented thinking, these aspects of a physicist's training have been recognized by companies in industry, finance, computing and consulting.

A thousand degree seekers

From 1983 to 2000 the Tevatron Fixed Target Program provided 465 students from 18 countries the opportunity to earn a masters or doctorate degree based on research carried out at Fermilab. Foreign universities, with Japan, Italy, Brazil and Germany being the top nations, granted about one third of the degrees. In the United States, 63 universities in 30 different states sent a total of 298 graduate students during those 17 years.

Though Fermilab constructed and provided the fixed-target facilities, physics students and their university advisors were the majority of users. Fermilab physicists represented 10 to 15 percent of the members of the fixed-target research collaborations. Additional users came from particle physics laboratories around the world.

The numbers are not yet complete. While data taking ended in January 2000, analysis for some experiments will continue for a few more years. About 50 more students are expected to graduate before the Tevatron fixed-target program will truly be complete. Adding the number of graduates related to the Main Ring fixed-target program (more than 200 from 1972 to 1983) and the Collider Program (more than 300 from 1991 to 2000), Fermilab's experimental particle physics program has created research opportunities for about a thousand students.

Will any of the former students be around when Fermilab's Main Injector Fixed Target Program starts in 2003? We expect at least some of them to return – as scientists and Ph.D. advisors. □

Preliminary number of physics students obtaining a university degree based on research at the Tevatron fixed-target program (1983-2000). The “total” column includes Ph.D., M.S. and diploma degrees, counting only the highest degree a student obtained. An additional 50 students will have graduated by the time all data has been analyzed, truly ending the Tevatron fixed-target program.

State/Country	PhD	Total		PhD	Total
Belgium	1	1	Brussels University	1	1
Brazil	13	21	Centro Brasileiro de Pesqu. Fisicas	8	13
			Federal University of Rio de Janeiro	1	1
			Pontificia Univ. Catolica Rio de Janeiro	1	1
			State University of Campinas	1	1
			University of Sao Paulo	3	5
California	26	26	Stanford University	1	1
			Univ. of California at Berkeley	3	3
			Univ. of California at Davis	7	7
			Univ. of California at Los Angeles	5	5
			Univ. of California at San Diego	1	
			Univ. of California at Santa Barbara	7	7
			Univ. of California at Santa Cruz	2	2
Canada	7	9	McGill University	3	5
			University of Toronto	4	4
Colorado	11	11	University of Colorado	11	11
Connecticut	7	7	Yale University	7	7
England	1	1	Imperial College - London	1	1
Florida	3	3	Florida State University	3	3
France	3	3	University of Paris - Sud	3	3
Georgia	1	1	Georgia State University	1	1
Germany	11	17	Technische Hochschule Aachen	1	1
			Max-Planck-Institut für Kernphysik	5	11
			Technische Universität München	2	2
			University of Freiburg	2	2
			University of Wuppertal	1	1
Greece	5	5	University of Athens	5	5
Hawaii	1	1	University of Hawaii	1	1
Illinois	41	46	Illinois Institute of Technology	2	2
			Northern Illinois University	-	5
			Northwestern University	7	7
			University of Chicago	19	19
			Univ. of Illinois at Chicago Circle	6	6
			Univ. of Illinois at Urbana-Champaign	7	7
India	3	3	University of Delhi	3	3
Indiana	16	19	Ball State University	-	1
			Indiana University	5	6
			Notre Dame University	11	11
Iowa	6	9	University of Iowa	6	9
Israel	2	4	Tel Aviv University	2	4
Italy	21	28	University of Bari	1	1
			University of Lecce	-	2
			University of Milano	9	13
			University of Pavia	10	11
			University of Roma	1	1
Japan	16	49	Aichi University of Education	-	1
			Kobe University	2	5
			Kyoto University	5	5
			Nagoya University	2	6
			Osaka City University	1	5
			Osaka University	4	12
			Toho University	2	7
			Utsunomiya University	-	8

State/Country	PhD	Total		PhD	Total
Kansas	3	3	Kansas State University	2	2
			University Kansas	1	1
Korea	4	6	Korea University	4	6
Maryland	5	5	University of Maryland	5	5
Massachusetts	23	23	Harvard University	4	4
			Massachusetts Inst. of Technology	4	4
			Northeastern University	8	8
			Tufts University	5	5
			Univ. of Massachusetts at Amherst	2	2
Mexico	6	10	Cinvestav	5	6
			Univ. Autonoma de San Luis Potosi	-	2
			Universidad de Puebla	-	1
			University of Guanajuato	1	1
Michigan	16	16	Michigan State University	8	8
			University of Michigan	8	8
Minnesota	7	7	University of Minnesota	7	7
Mississippi	1	1	University of Mississippi	1	1
Missouri	1	1	University of Missouri	1	1
Netherlands	1	1	Universiteit Antwerpen	1	1
New Jersey	10	10	Princeton University	4	4
			Rutgers University	6	6
New Mexico	2	2	New Mexico State University	2	2
New York	32	33	Columbia University	16	16
			St. Univ. of New York at Albany	1	1
			St. Univ. of New York at Stony Brook	3	3
			University of Rochester	12	13
North Carolina	5	5	Duke University	5	5
Ohio	11	11	Case Western Reserve University	1	1
			Ohio State University	5	5
			University of Cincinnati	5	5
Oklahoma	1	1	University of Oklahoma	1	1
Pennsylvania	15	15	Carnegie Mellon University	2	2
			Carnegie Melon University	3	3
			Lehigh University	1	1
			Pennsylvania State University	2	2
			University of Pennsylvania	3	3
			University of Pittsburgh	4	4
Puerto Rico	-	6	University of Puerto Rico	-	6
Russia	1	1	Moscow State University	1	1
South Carolina	1	1	University of South Carolina	1	1
Switzerland	1	1	University of Geneva	1	1
Taiwan	1	1	National Cheng-KunUniversity	1	1
Tennessee	6	6	University of Tennessee	4	4
			Vanderbilt University	2	2
Texas	13	15	Rice University	10	12
			Texas A&M University	1	1
			University of Houston	1	1
			University of Texas at Austin	1	1
Virginia	5	5	University of Virginia	5	5
Washington	7	7	University of Washington	7	7
Wisconsin	8	8	University of Wisconsin	8	8
U.S. universities	284	298			
Foreign univ.	97	167			

NEXT TARGET:

The Fourth Neutrino, and Maybe More

by Mike Perricone

Alexandre Dumas's classic adventure, *The Three Musketeers*, actually centers on the story of D'Artagnan—a fourth musketeer-in-waiting.

Does the classic Standard Model tale, *The Three Neutrinos*, have its own D'Artagnan—a fourth neutrino-in-waiting, ready to emerge as the focus of the story?

The answer might come from Fermilab's next generation of fixed-target experiments.

"The clearest part of our future is the neutrino program," lab director Michael Witherell said during the June 2 fixed-target symposium. "We're in midst of building a new round of Fermilab neutrino experiments. MINOS is pushing towards starting to see neutrinos early in 2003. And MiniBooNE, using the booster beam, is on a very fast track to start taking data in 2001."

The Standard Model includes three types or "flavors" of neutrino: electron, muon and tau. Quantum mechanics declares that neutrinos which change or "oscillate" from one flavor to another must have mass, and experimenters have thus far seen indications of neutrino oscillations in three ranges of mass differences: in solar neutrinos, in atmospheric neutrinos, and in an accelerator experiment at Los Alamos National Laboratory, the Liquid Scintillator Neutrino Detector, which has shown signs of the largest mass difference (noted as "(m2") among the three by far.

As with any physics issue, answers raise further questions.

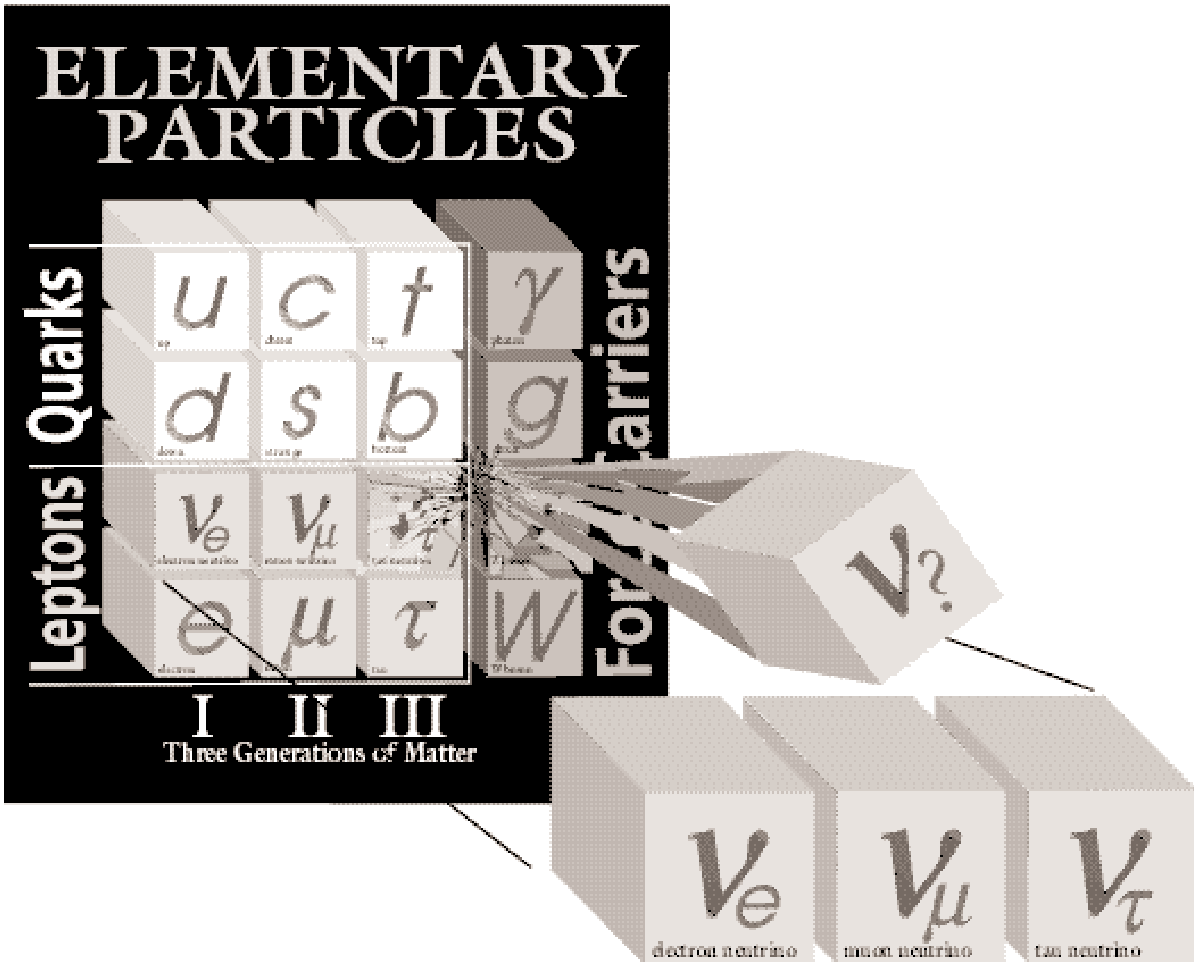
"Which forms are oscillations, and what are the oscillation parameters?" asked Witherell. "Are they all really neutrino oscillations? If so, then we need a fourth neutrino that doesn't fit in [the Standard Model]."

Why a fourth neutrino? It's a matter of mathematics.

"There are only three neutrinos that we know, and we say each corresponds to a different mass," said Associate Director for Research (and veteran neutrino experimenter) Mike Shaevitz. "With three numbers, you can't generate three different (m2 results. We can't explain three results with three neutrinos. We need a fourth neutrino."

The fourth neutrino is postulated as the "sterile" neutrino. Or maybe that's only the start; maybe "sterile" is just a figure of speech, and the neutrinos -in-waiting just beget more and more of them.

"There is no reason to think there is only one sterile neutrino. I would argue that the most natural number is three, one for each family," said Janet



Conrad, cospokesperson of the MiniBooNE experiment, a critical element in the next fixed-target run.

"There is a quip going around in neutrino circles," Conrad continued, "and I don't know who said it first, and I'm not sure I want to know. But the quip goes: 'Sterile neutrinos are like cockroaches. Once you get one in your theory, there's no stopping them.' Theorists either love or hate the sterile neutrino. There is nothing in between."

But there's plenty at stake.

MiniBooNE will use beam from the Booster accelerator for a short-baseline fixed-target experiment, expected to begin taking data late in 2001 via a 12-meter sphere filled with mineral oil and photomultiplier tubes. The goal: confirm with thousands of events the LSND indications of the appearance of electron neutrinos in an initially pure beam of muon neutrinos. Operating in the range of largest mass-difference, MiniBooNE can utilize a short time of flight for possible neutrino oscillations that might confirm the critical LSND possibility.

"At this point," Conrad said, "we cannot resolve the picture without knowing 'yes' or 'no' on LSND."

Even a 'no' contains further possibilities, but a 'yes' raises the stakes immeasurably.

"Confirming the LSND experiment is the result that would most change our picture of neutrinos and change where we're going in the future to study neutrinos," Witherell said at the symposium. "Experimentally, we could be wining the lottery...because there would then be so many things can do."

The lottery prize of a MiniBooNE confirmation would include the fourth neutrino, with all the associated theoretical and experimental explorations; and a new generation of accelerator-based neutrino experiments, using short pathways like MiniBooNE—opening another pathway to "new physics" beyond the Standard Model.

Neutrinos easily make their own pathways through just about anything, including the earth—even the 450 miles of earth between Batavia and a mineshaft a half-mile below the surface in Soudan, Minnesota.

NEXT

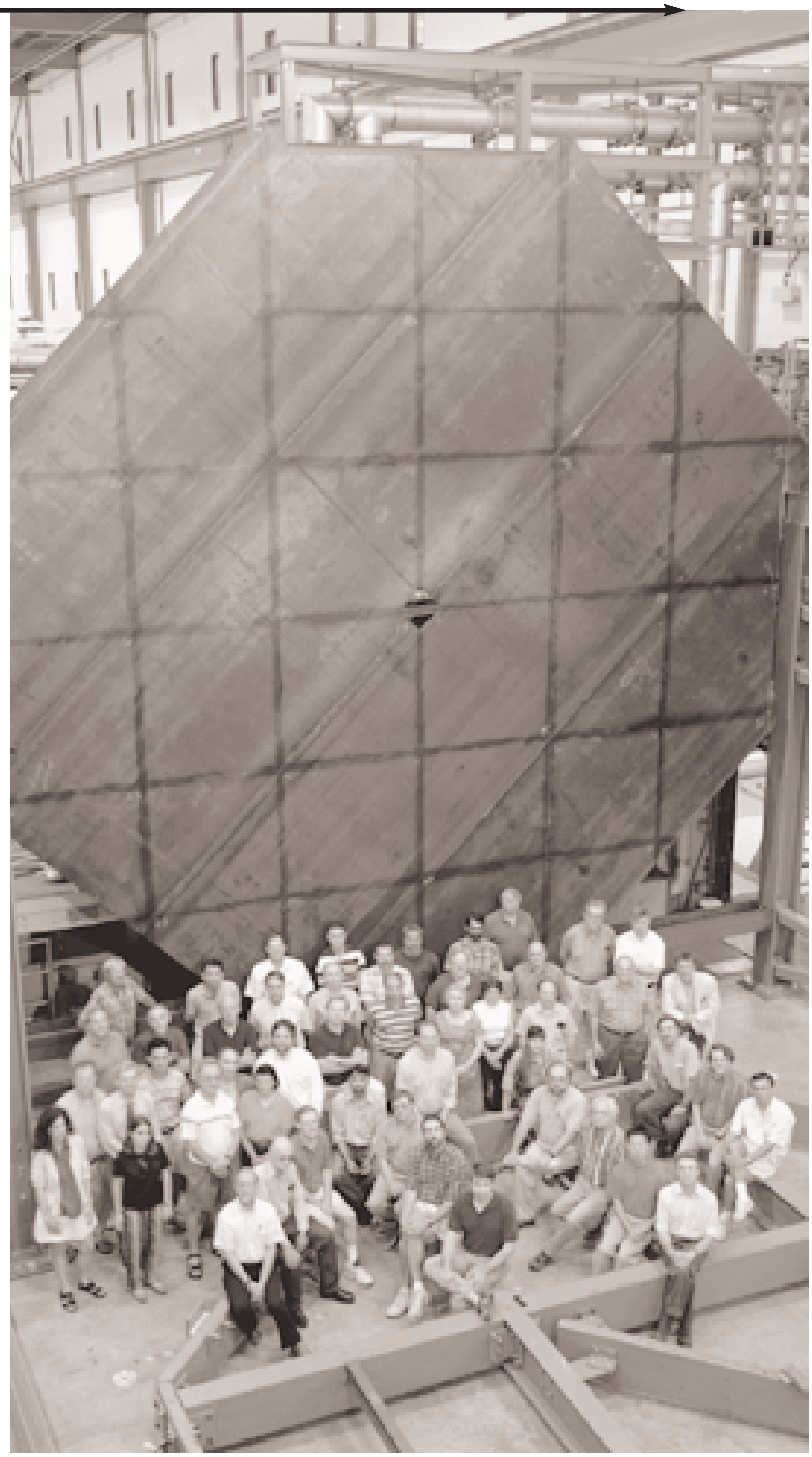
The Main Injector Neutrino Oscillation Search leads the next generation of fixed-target experiments using the high-intensity, 120 GeV proton beam from the new Main Injector. Part of the NuMI project (Neutrinos at the Main Injector), the long-baseline MINOS experiment will explore the very small mass-difference range of oscillations from muon neutrinos to tau neutrinos. The $30-million civil construction project to dig the 1500-meter tunnel at the lab for MINOS had its groundbreaking on May 31.

The Main Injector's intense proton beam would also drive two proposed fixed-target experiments in CP violation, the exploration of asymmetries between matter and anti-matter.

The Charged Kaons at the Main Injector (CKM, honoring the Cabbibo-Kobayashi-Masakawa mixing matrix) intends to measure the branching ratio of the rare charged kaon decay producing charged pions, neutrinos and antineutrinos. The Kaons at the Main Injector experiment intends to investigate the ultra-rare decay of neutral kaons producing neutral pions, neutrinos and antineutrinos; KAMI would use the former Kaons at the Tevatron (KTeV) detector, which has already produced direct evidence of CP violation in neutral kaon decays.

Witherell was clear that the lab's priority centers on Collider Run II of the Tevatron. But he voiced a one-for-all and-all-for-one level of support for the lab's "superb program in the fast developing field of neutrino physics."

"This is an area that has been hot for a while, and will continue to be for some years," Witherell said. "We're going to know a lot more in five or six years than we know now." □



Photos by Reidar Hahn

The MiniBooNE detector (top left) required a cylindrical excavation forty feet deep and fifty feet in diameter. The completed detector houses more than a thousand photomultiplier tubes and holds 239,000 gallons of mineral oil. The MINOS collaboration (above) illustrates the scale of one of the detector plates destined for the mine shaft in Soudan, Minnesota.

CALENDAR

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

INTERNATIONAL FILM SOCIETY Presents

Grand Illusion (La Grande Illusion) Dir: Jean Renoir, France (1937), 120 min., 8 PM; tickets: $4, Ramsey Auditorium, Wilson Hall. Erich von Stroheim as the commandant makes an indelible impression, as a man deluded by romantic notions of chivalry and friendship.

ARTS SERIES Presents: Arlo Guthrie

Tickets: $25; 8 pm, Ramsey Auditorium, Wilson Hall. Arlo gave his first performance at age 13 and quickly became involved in the music that was shaping the country during the 1960's. Arlo's career soared in 1967 with the release of Alice's Restaurant, a song that helped foster a new commitment among his generation to social activism and consciousness.

ONGOING

■ NALWO is pleased to announce the free morning English classes in the Users' Center for FNAL guests, visitors, and their spouses have been expanded; The new schedule is: Monday and Thursday, 9:30am - 11am beginners (Music Room) and intermediates (Library) Monday and Thursday, 11am - 12:30pm advanced, emphasizing pronunciation and American idioms (Music Room)

■ NALWO coffee for newcomers & visitors every Thursday at the Users' Center, 10:30-12, children welcome. In the auditorium, International folk dancing, Thursday, 7:30-10 p.m., call Mady, 630-584-0825;

■ The Recreation Office will again be providing children's swim lessons for employees, users and on-site contractor children ages 5 - 12. For information pick up a brochure at the Recreation Office, Users Office, Housing Office, or Children's Center. You may also get info from our website: http://fnalpubs.fnal.gov/benedept/recreation/pool.html Jeanmarie Guyer Recreation Office M.S. 126 P.O. Box 500 Batavia, IL 60510 Phone (630)-840-2548 Fax (630)840-5207

BARN DANCES

All dances are taught and people of all ages and experience levels are welcome. Admission is $5, children under 12 are free (12-18 $2). The barn dance is sponsored by the Fermilab Folk Club. For more info, contact Lynn Garren, x2061, garren@fnal.gov or Dave Harding, x2971, harding@fnal.gov.

Chez Léon MENU

Lunch served from 11:30 a.m. to 1 p.m.
$8/person

Dinner served at 7 p.m.
$20/person

For reservations, call x4512
Cakes for Special Occasions
Dietary Restrictions
Contact Tita, x3524
http://www.fnal.gov/faw/events/menus.html

LUNCH
Wednesday, July 5

Closed

DINNER
Thursday, July 6

Closed

LUNCH
Wednesday, July 12

Danish Open Sandwiches
Summer Fruit
With Honey Almond Cream

DINNER
Thursday, July 13

Tortellini with Pesto Sauce
Beef Tenderloin
Potato Gratin
Green Beans
Salad of Greens
Crepes with Berries

LUNCH
Wednesday, July 19

Dominican Roast Beef Salad
Tropical Root Vegetables
Pineapple Flan

DINNER
Thursday, July 20

Eggplant, Tomato, Basil and Fresh Mozzarella Towers
Lime glazed Seafood Kebobs
Green Rice
Profiteroles with Fresh Fruit

LUNCH
Wednesday, July 26

Wild Rice and Chicken Salad with Tarragon
Raspberry Sorbet with Berries

DINNER
Thursday, July 27

Risotto Cakes with Shrimp and Veal Scallopini with Morel Sauce
Hazelnut Pear Souffle

F N E E R W M S I

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CLASSIFIEDS

FOR SALE

■ '99 Harley Davidson Sportster Custom XL883C (Black) 3,000 miles, windshield, forward controls, saddle bag brackets and a touring seat. Asking $7,500. Terry X4572 (skweres@fnal.gov), or Janine (none2compare@yahoo.com).

■ '99 Goldwing SE (Silver) with extras. Price dropped to $14,500—lower than new. 11K Miles - excellent condition, runs great, markland receiver hitch and 5-pin OEM trailer wiring kit, markland floorboards, foam grips, extra windshield, 2 headsets for the intercom. Still has 2 yrs on original as of Nov. 5 (unlimited miles) warranty. Can get another 3 yrs extended (unlimited miles). Call Terry X4572 or e-mail skweres@fnal.gov

■ '96 Ford Explorer, "Eddie Bauer", V-8 automatic, 35,000 miles all accessories, inc. JBL, CD changer stereo system, cassette, moon roof, lighted sun visor, leather power seats, Lady driver, one owner, very very nice SUV. $19,950.00 obo. Mike x3924, or 847-426-1596.

■ '91 Honda Accord EX, 5 speed, power windows/locks, moonroof, 164K. Well maintained and in very good condition. $3,400. Call Jeff at x3951, or 630-876-3293.

■ '90 Honda Civic Si Hatchback, 3 door, very reliable, good condition inside and outside, 2 years new tires and breaks, new timing belt, 100kmi, A/C, 5 spd, moonroof, $3,150. 630-355-1253 or chendi@fnal.gov.

■ '88 Toyota Corolla, automatic, 103K miles, AM/FM Radio, $1950 OBO Call 630-840-3547 or e-mail: gradinu@yahoo.com

■ '88 Plymouth Sundance 4-Door hatchback excellent condition 105,000 miles, new brakes, battery and radiator $2,000 obo x8295 x3604 428-0024 (evenings) gerber@fnal.gov

■ '77 Honda Goldwing 1000, excellent condition with Vetter fairing and packs, 66K miles. Lots of extras. Asking $1,000 or best offer. Contact Gary at 896-6196 evenings.

■ 13' Aqua Cat catamaran sailboat with trailer. Like new condition, $1,000/best offer. Gerry 630-961-7722.

■ Time Share—Acapulco / Puerto Vallarta / Mazatlan, 1-bedroom unit / sleeps 4-6 Appraised @ $ 15.9 K. Call Duke @ 815-372-2368 evenings after 7:00PM &/or anytime weekends.

■ Guitar: Dobro, metal body, spanish neck, spideer bridge resonator. Mid 1980's model 33H, etched Hawaiian scenes on chrome plated brass. VGC, $900 with case. Amplifier Marshall AS80, like new $375, Fender reverb 30, good condt, $125, call Curtis x2394 or crawford@fnal.gov.

WANTED

■ A reasonable car for driving to work, an apartment with 2 bedrooms. Please call Jeff Ruffin x4432.

■ Rent a room (in home private home or otherwise) till August 10th or so. Rent is highly negotiable. Sourobh at sourobh@fnal.gov or University of Illinois at Urbana-Champaign raychaud@uiuc.edu

■ BABY SITTING needed for my 6 years old during summer - Ideal for high schooler or college girl -time: M-F 9:30 am to 6pm (afternoons at the Fermilab pool!!) pay: $40/day weeks from June 5 to July 21, 2000, must have use of a car. 630-840-2574 or 983-3575 (eve), 10 minutes from Fermilab.

FOR RENT

■ Newly redecorated 1 and 2 bedroom apartments available. $550 - $750 / month. 630-892-5257

■ 3-4 BR ranch on wooded 3/4 acre in Delnor area of St. Charles. LR & FR w/see-thru FP, dining area, central air w/EAF, 2 car attached garage, basement, appliances. 1 year lease minimum, 2 month deposit, no animals, $1,700/month, available 10 July. Leo 630-584-2199.

BIBLE STUDY

■ The 12 o'clock (noon) Bible16y. Everyone is welcome. If interested contact Jeff Ruffin x4432, or ruffin@fnal.gov .

MILESTONES

URA SCHOLARSHIPS

■ Naomi Telitha Maeshima Williams (parent/s: Kaori Maeshima - CMS(CDF)/PPD); University: University of Illinois at Champaign-Urbana.

■ Lauren Alexandria Tompkins (John Tompkins – TD); University of California-Berkeley

■ Tom Y Tang (Zhijing Tang – PPPD); University of Illinois at Champaign-Urbana

■ Eric Tsai Syu (Ji-Jung (Joseph) Syu - CD/ISD/ISA); Massachusetts Institute of Technology

■ Brandon Robert Stolz (Michael Stolz – CD); Milwaukee School of Engineering

■ Christina Nobrega (Fred and Lucy Nobrega – TD/Enrg. & FAB); Northern Illinois University

■ Susan Elaine Johnson (Glen C. Johnson - BD/Controls); Carleton College, Northfield, Minn.

■ David Marvin Slaughter Johnson (Marvin Johnson - D-Zero, Jean Slaughter - visitor CDF/E791); Yale University

■ Joseph Frank Jaskierny (Walter Jaskierny - PPD/ETT); Loyola University of Chicago

■ Margaret Ann Harding (David J. Harding - TD/Headquarters); University of Wisconsin at Madison

■ Youjia Chen (Dirong Chen – BD/EE Support):University of Illinois at Champaign-Urbana

■ Stephanie Butler (Joel Butler – PPD); Harvard College, Cambridge, Mass.

■ Joan Eunjoe Ahn (Seung-Chan Ahn – BD/Controls); Amherst College, Amherst, Mass.

http://www.fnal.gov/directorate/public_affairs/ferminews/

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