FERMI NEWS

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Going All-Out **2**

Photo by Reidar Hahn

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INSIDE:

Going All-Out

MAIN INJECTOR PREPARES TO ACHIEVE SEVENTH AND FINAL COMMISSIONING GOAL.

by Mike Perricone

The Main Injector had been running beam for just over 20 days when commissioning crews rang up the sixth of their seven formal commissioning goals on Wednesday night, January 6, 1999.

That's just under three full weeks with a proton beam running through the new $230 million accelerator. Three weeks scheduled around simultaneous commissioning activities and installations. Three weeks apportioned over winter evenings and weekends, from the first injection of a hair-thin stream of protons to a point where the final commissioning goal is within reach.

"With 20 days of beam, I think we're doing a reasonably good job," said commissioning chief Shekhar Mishra of the Beams Division's Main Injector Department.

Like a team in the final round of the playoffs, the Main Injector commissioning crews know that a successful sixth goal is like a successful sixth game: it sets up the decisive final confrontation.

To reach their sixth goal, the crews had to show that the machine could "bulk up" on protons enough to fill the next stage of Fermilab's accelerator complex: the four-mile ring of the Tevatron, the adjacent site of the proton-antiproton collisions in Fermilab's next collider run beginning just after the turn of the century.

The criteria for the sixth commissioning goal: a total of 2×10^{13} protons to fill a cycle of the Tevatron. That meant filling the two-mile Main Injector with 1×10^{13} protons at 150GeV per cycle; two cycles of the Main Injector would thus fill one cycle of the Tevatron. The crews prepared for another long workday, after most of the Lab was dark, with dinner over a desktop or during a quick dash home if home was close enough to make the round trip reasonable.

Alongside the sixth goal came another milestone (though not itself a formal commissioning goal), with the first proton beam extracted from the Main Injector and sent to a transfer line toward the Tevatron. The 8.9 GeV beam didn't reach the Tevatron but it did get as far as the FZero "switching junction" between the accelerators; not yet cooled to its superconducting state, the Tevatron is not prepared to accept beam.

But building an accelerator leaves no margin to rest on success. No sooner was the sixth goal reached than the seventh and final goal became an all-consuming focus and a major challenge, with documentation for the machine's full commissioning due with the Department of Energy by early spring.

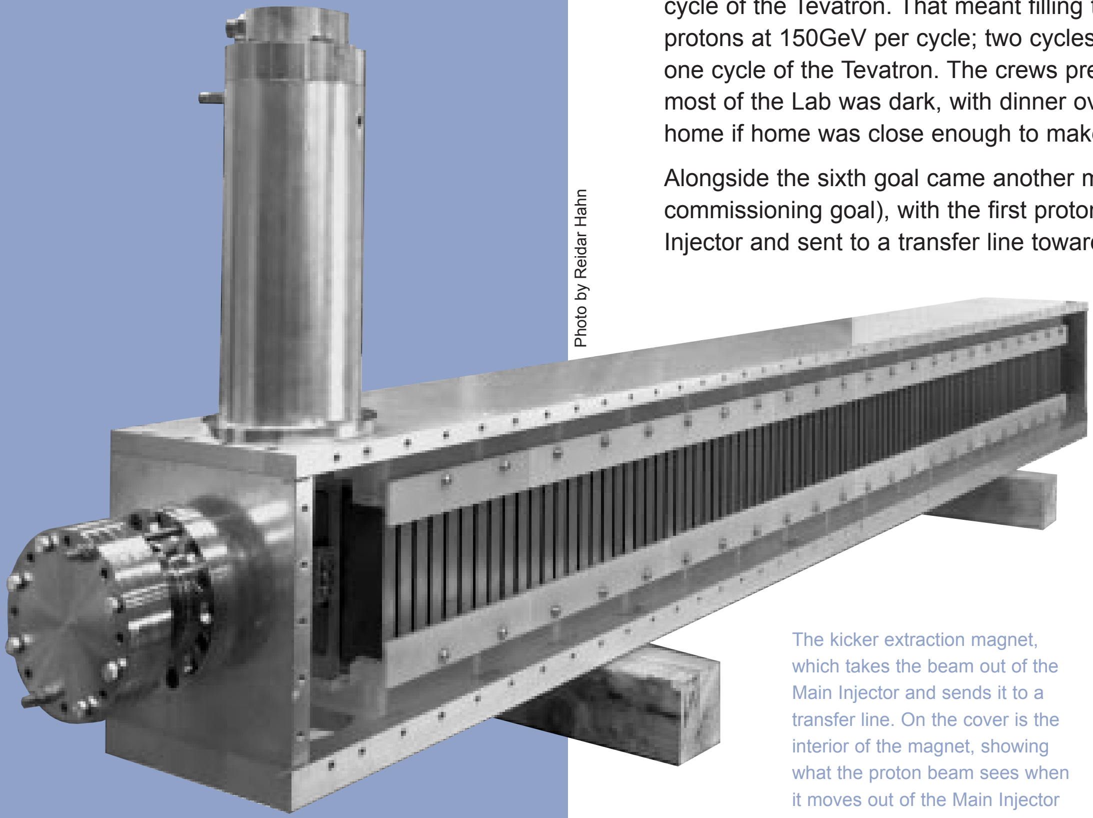


Photo by Reidar Hahn

The kicker extraction magnet, which takes the beam out of the Main Injector and sends it to a transfer line. On the cover is the interior of the magnet, showing what the proton beam sees when it moves out of the Main Injector on its way to the Tevatron.

The seventh goal stands as the all-out seventh game of the playoffs for the Main Injector. The goal represents a final stretch of the accelerator's capabilities: a high intensity beam of 2x10^{13} protons extracted in what's called a "slow spill," maintaining a uniform intensity for up to a full second while the near-light-speed beam is being removed from the Main Injector.

Normal extraction times are measured in millionths of a second, and protons will make nearly 100,000 turns around the two-mile accelerator in the course of a full second. The slow extraction is designed to satisfy future experiments, including the Neutrinos at the Main Injector (NuMI) project and proposed experiments such as Kaons at the Main Injector (KaMI). No current experiment requires a high-intensity slow-spill extraction.

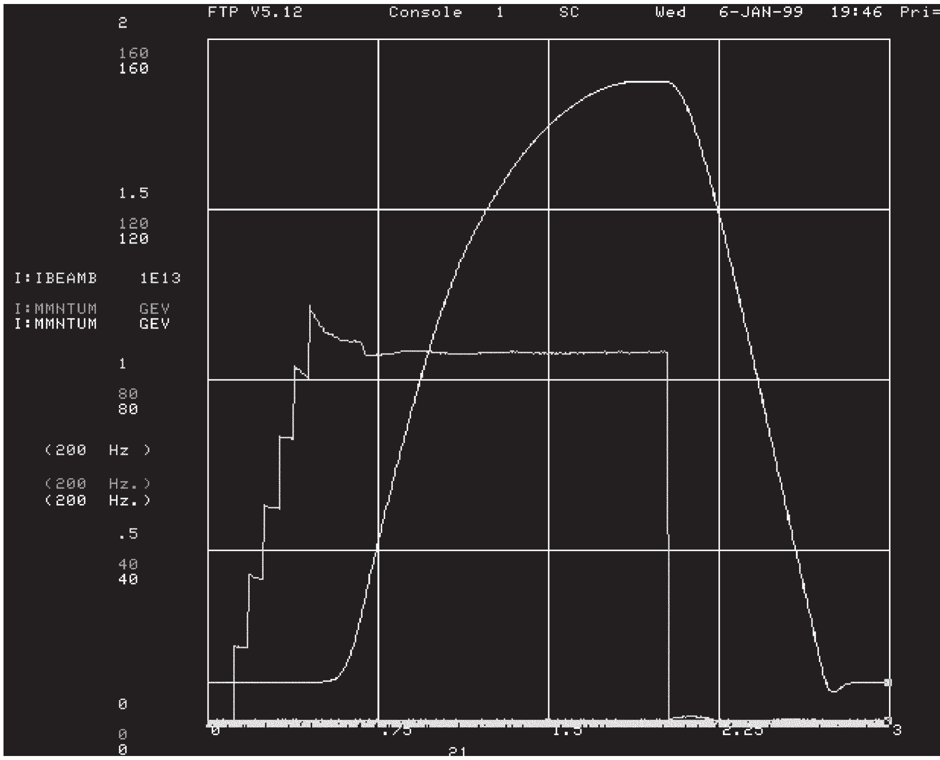
But a goal is a goal, and this goal is specifically mandated by the commissioning standards for the accelerator set in agreement with the Department of Energy. The slow spill operation requires a system of "dampers" to stabilize the high-intensity beam over the comparatively huge length of time for the beam's extraction.

"It is a pretty big deal," Mishra said. "When you have so much beam, it tends to become unstable. Some of the slow spill hardware has already been installed, but there is more that needs to go in. We think it can be done in about ten days, although it will be a very intense ten days."

The Main Injector schedule now calls for a 10-day shutdown from January 14 through January 23, to complete installation of the slow spill system and to advance the installation of the Recycler, which shares the Main Injector tunnel. Beams Division head Steve Holmes hopes to have some extra manpower for that job, with other divisions pitching in to help meet the deadline.

"We had five technicians from the Particle Physics Division and a few from the Technical Division working with us most of the fall, and they made a great impact," Holmes said. "We'd like to get that kind of help again."

After the shutdown, Holmes hopes to reach the slow spill commissioning goal by February 15.



Graphic courtesy of Beams Division

Goal No. 6: The hill-like curve starts from 0 and reaches 150 at between 1.5 and 2.25 seconds—meaning the Main Injector has achieved an energy of 150 GeV (billion electron volts). Meanwhile, the jagged line peaks and settles to a plateau just above a value of 1x10^{13}—meaning the Main Injector has achieved Goal No. 6.

Then the machine would be shut down again for six to eight weeks to complete installation of the Recycler. By mid-April, commissioning should resume again, this time for the Recycler, the Antiproton Source and the Tevatron; then beam would be sent to the Tevatron to be used in fixed-target experiments.

Most recently, the Main Injector schedule has survived the failure of one of the 12 transformers powering the dipole magnets, possibly a casualty of the heavy snowfall buffeting the Lab throughout January. That transformer will be replaced during the February shutdown; meanwhile, the remaining 11 transformers are carrying the load.

They could also be carrying a message: It's time to go all-out. The seventh goal is the seventh game.

PIECING THE TEVATRON TOGETHER AGAIN

by Sharon Butler

With the intense activity surrounding the commissioning of the Main Injector, the Tevatron has all but been forgotten. By some.

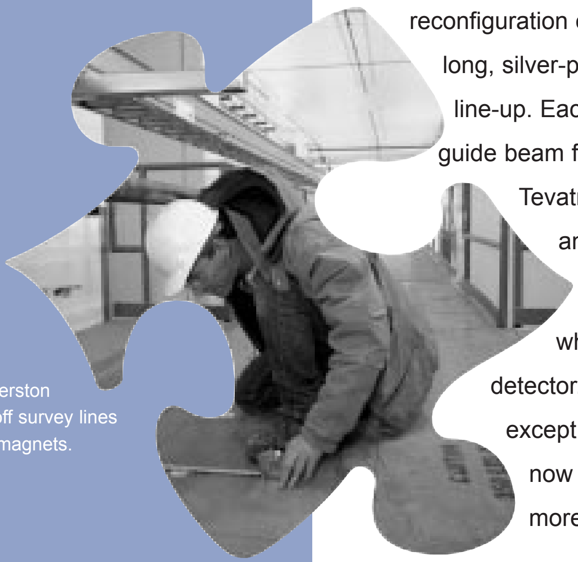
Others have been quietly hard at work. Like the mechanical support crews, who have been emptying sections of the tunnel, pulling out magnets for repairs, and reinstalling old magnets or inserting brand new ones, piecing the Tevatron together again.

Since the start of the shutdown 18 months ago, the crews have been working 10-hour shifts on weekdays and 8-hour shifts on Saturdays. A second evening shift was added in July. Crew member Jim Holub remembers, because that was the start of the bowling season he had to miss.

For contractor crews reinstalling the cryogenic pipelines in areas disrupted by construction, the recent subzero temperatures haven't helped. Fermilab engineer Alex Martinez said they've had to build huts to block the wind while they're welding, and have sometimes had to dig pipes out from underneath two feet of snow.

If all goes according to schedule, the Tevatron will be chilled to superconducting temperatures again on March 1, and its superconducting magnets will be ready to accept beam from the Main Injector and ramp protons up to higher and higher energies. But in important ways, this reincarnation of the Tevatron looks different. At the location designated FZero, for example, magnets and utilities (like cables and pipes) were removed to allow for a reconfiguration of the tunnel, and then reinstalled. Spanking new 10-foot-long, silver-painted Lambertson magnets have been added to the magnet line-up. Each weighing as much as two elephants, the Lambertsons will guide beam from the Main Injector into the circulating beam in the Tevatron; when they are turned off, beam is shunted out to the antiproton source or to fixed-target areas.

Major construction work also took place at location CZero, where an experimental hall was built to accommodate a future detector. The profile of that section of the Tevatron remains the same, except that, where the experimental hall is deep, special stands now raise the magnets seven feet off the ground (instead of the more typical few inches).



John Featherston measures off survey lines to position magnets.

Bob Furst (kneeling) and Brian Howell connect the interfaces between magnets.

Photos by Reidar Hahn

Approximately 29 superconducting dipoles, at locations scattered around the ring, have also been repaired by the Technical Division. The original leads had been tied with nylon tie-wraps which, damaged by radiation over time, became brittle and fell off. With the repairs, the leads will remain stable, preventing magnet failures.

When the Tevatron cranks up again this spring, it will be delivering beam to fixed-target experiments. And Beams Division staff are hoping to use that run to test and develop novel items introduced in the accelerator to improve operations in next year's collider run.

One item, at location E0, is a "dog leg"—an angular bend in the line-up of four old Main Ring magnets—with new collimators, or steel jaws, to scrape off protons. The aim is to more efficiently recycle antiprotons. "At the end of a store, there are both protons and antiprotons in the machine," said Mike Church. "It will be easier to recycle the antiprotons if you first scrape away the protons. Then you can center the beam of antiprotons, decelerate it, and get it back into the Recycler."

The new collimators will also be used to "scrape" the beam halo, or stray protons that can get into the detectors and create annoying excessive background for experimenters. Placed at strategic points around the ring, the collimators can be moved, by remote control, close to the beam so that the beam halo hits these devices rather than the detectors.

Other hardware under development for Run II includes a new damper system, also at the E0 location, which will make the Tevatron beam stable at high intensities.

Once the magnets are all installed and connected, their vacuum systems are checked for leaks: an exhaustive and heroic task. But before the big chill—the cooldown—can begin, all moisture has to be purged from the cryogenic pipes, the refrigeration system and the magnets. In certain segments of the ring, that process began three weeks ago. Dry nitrogen gas is repeatedly flushed through the system, driving out any moisture that might freeze when the cooldown begins, clogging valves and other equipment.

The cooldown itself is scheduled to begin February 1, according to Barry Norris, group leader for cryogenic systems. It involves several stages. The first is a leak check, or what Norris likes to call, more descriptively, a leak hunt. Norris explained that helium leaking from the cryogenic system into the tunnel through broken or improperly connected parts can be costly, because helium is so expensive. The nitrogen is then pumped out and the system then backfilled with helium. Next, the helium is passed through filters as it circulates through the entire system. Any nitrogen in the system, like any drops of moisture, can clog parts, since nitrogen freezes before helium. The aim of the purification process is to reduce the amount of nitrogen to less than 5 parts per million.

Finally, the real cooldown can begin, dropping temperatures in the superconducting magnets to 4.5 degrees Kelvin.

Barring unforeseen circumstances, Church said the Tevatron would be cold by March 1—ready in plenty of time to take beam from the Main Injector.


Jim Holub tests for leaks in the vacuum system.


Photos by Reidar Hahn

Gary Coppola surveys in the Tevatron tunnel.

Wunderlich ★ Will Manage ★ the Mission ★ for DOE's ★ Fermi Group

by Mike Perricone

Photo by Jenny Mullins

Bob Wunderlich, the new Acting Manager for the Department of Energy's Fermi Group, sees himself as a man on a mission.

"It's a joint mission with the Laboratory," said Wunderlich, who moved over from his position as Assistant Manager for the Argonne Group, at Argonne National Laboratory, following the retirement of Andy Mravca on January 2.

"My job is to make sure the programs at Fermilab get started, keep moving efficiently, and are successful," he continued. "We've decided on what we're going to do, now how do we get there? My focus will be on that sense of mission."

Wunderlich's sense of mission stems from his three years in the Marine Corps. He joined right after high school, spending a year in Vietnam.

"I was a rifleman in an infantry company, the Third Battalion, Fifth Marines, arriving right at the end of the Tet offensive," he recalled. "I spent my first three months up in the bush. The fortunate part is they moved their location to an area accessible by road and got a company jeep. They made me the jeep driver. So there was no more being on point, or carrying the radio. I didn't go into the bush any more, which is probably why I'm here today."

After the Marines, Wunderlich got his bachelor's degree in mechanical engineering from Penn State in 1973 on the GI Bill. He added a master's in nuclear engineering through an Atomic Energy Commission training program, then interned for a year in reactor safety analysis at Argonne in 1976, where Mravca tried to hire him. But Wunderlich headed back to Washington for more training. He returned to Argonne in 1989, after five years as a reactor engineer at DOE headquarters and 10 years in the Civilian Radioactive Waste Disposal Program.

Wunderlich served seven years as project manager for Argonne's $800 million Advanced Photon Source accelerator—"and it was completed on cost and on schedule," he emphasized, building a cooperative relationship with Argonne management that he cited as a high point of the project. His assistant for three years was DOE Main Injector project manager Ron Lutha, once again a colleague in the Fermi Group.

"This is going to be a good place to work," Wunderlich said. "Fermilab has always had the reputation of doing premier science, and of doing a lot with a little."

Wunderlich, married for 29 years, lives in Woodridge. His wife, Cynthia, is a computer programmer with Electronic Data Systems in Chicago. They have three sons and three grandchildren: a boy, three years old, and two girls, a year old and a month old.

"They're a lot of fun," Wunderlich beamed. "They're my hobby now."

SNOW
News Was Good News

…WITH FERMILAB CREWS PLOWING OUT FROM UNDER A RECORD WINTER STORM

Photo by Jenny Mullins

Photos by Reidar Hahn

Crews removed the snow from 380 acres of parking lots.

by Judy Jackson

With the New Year came the snow: first a few flakes, then a few more, then The Blizzard of '99. It started snowing on New Year's Day; by the time it stopped two days later, the Chicago area was buried under the second-largest snowfall ever recorded. Midwest airports closed, streets disappeared, the north wind howled and temperatures plunged to bone-chilling levels. At Fermilab, it was beginning to look a lot like winter.

Almost as soon as the storm began, Fermilab crews went to work to keep the Laboratory's roads clear. Summoned to an early return from the 12-day holiday break, they worked around the clock, with only three-to-four hour breaks to catch up on sleep. The 18-man team operated plows, front-end loaders, snowblowers and shovels to clear the 25 miles of roads, 380 acres of parking lots and countless walks and driveways on Fermilab's 10-square-mile site.

As a result, while the rest of Chicagoland slipped, skidded and slid to work on the first workday of 1999, the Fermilab staff arrived at the Laboratory on Monday to find clear roads, plowed lots, and towering banks of piled snow.

"We moved many more cubic yards of snow than ever before at Fermilab," said Mike Becker, of the Laboratory's Roads and Grounds Department, who with colleague Bob Lootens managed the snow job. "In 1979, there was more snowfall, but Fermilab had far fewer paved areas, so there was much less snow to move."

The crew manned seven pick-up mounted plows, six large dump-truck plows, front-end loaders, snowblowers and shovels, with crew members taking shifts on all the different equipment, from shovels to loaders, so that no one got stuck doing the same job for hours on end.

Becker had praise for both his crew and their tools.

"Most of our snow equipment is relatively new and well maintained," he said. "We have a mechanic on duty throughout the snow operations. When he's not needed to fix something, he jumps on a plow to help out. We have reliable people and reliable equipment. You need both to deal with a snowstorm."

One crucial piece of equipment never left the snow crew's central shop.

"We keep a coffee pot going at the shop," Becker said. "We keep it hot around the clock. And we designate a couple of people at each meal as cooks. This morning, Bob Lootens and Martin Valenzuela made pancakes and eggs for us for breakfast."

Later in the week, as more snow fell, crews continued digging out from the first storm. Crew member Joe Trevino maneuvered a front-end loader, piling snow from a parking lot at a service building for Fermilab's new Main Injector accelerator. Trevino had arrived at Fermilab along with the first snowflakes and had worked steadily ever since, pausing now and then to catch some sleep. He described conditions during the worst of the storm, when winds gusted to 45 miles per hour.

“The wind is the worst,” Trevino said. “You just get an area cleared, and the wind blows the snow back. You say to yourself, ‘When is this gonna stop?’”

Ray Fonseca, who manned a snow shovel in the area around Fermilab’s High Rise, said shoveling was the only way to keep walks clear when temperatures dropped below about 10 degrees Fahrenheit. “De-icing compounds don’t melt the snow when it’s really cold,” Fonseca said. “You have to use a shovel.”

In the Fermilab Village, the little red, orange and blue houses looked like Vermont mountain hideaways or Colorado ski lodges under their thick frosting of snow. With roads and parking lots plowed, the snow crew could turn to the less urgent tasks of clearing walkways. Steve Whiteaker shoveled a path to the front door of one Village home. He and Larry Thomas, who was operating a snow blower a few blocks away, had to rely on memory to find the buried walks to Village houses. Fortunately, they remembered most of them from summer lawn-mowing duty.

“Be sure to check the pathways to the Children’s Center,” Becker reminded them.

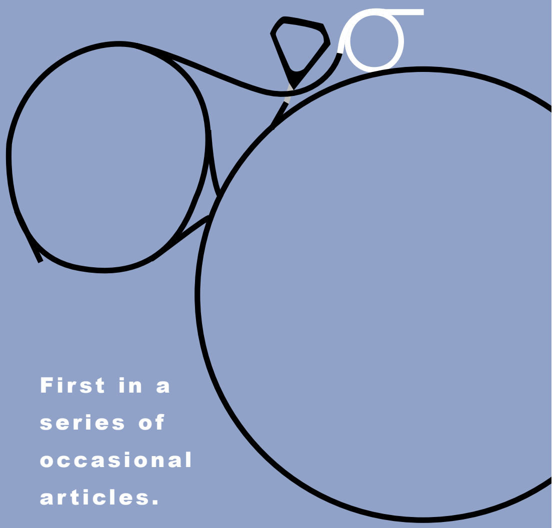
A mile or so away, Roads and Grounds crew member Jim Kalina was rescuing a low-slung car from a five-foot snowdrift. Earlier, Kalina had uncovered the vehicle’s Fermilab identification sticker and determined that its physicist owner was attending a conference in Vancouver, British Columbia, where weather reports showed sun, with temperatures in the fifties.

Asked about predictions for more snow in northern Illinois in coming days, Kalina responded, “Let it come. I’m ready.”

As snow drifted across the open prairie, plows cleared the 25 miles of roads on the Fermilab site.

How to Make a PROTON BEAM

Follow THE PARTICLES



First in a series of occasional articles.

by Mike Perricone

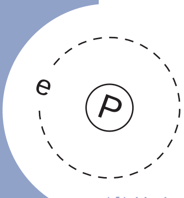
At $150, the cost of the raw material for a year's worth of protons at Fermilab is approximately the same as a cup of cafeteria coffee each workday throughout the year.

The source of the protons: a bottle of hydrogen gas, obtained from a commercial supplier. It looks like a propane canister for your backyard gas grill.

Hydrogen, listed first on the Periodic Table of the Elements, is the most abundant element in the universe, the primary fuel for the fusion reactions producing the heat in the sun and all the stars. The simplest of atoms, with a single proton and a single electron, hydrogen forms a colorless, odorless, tasteless and highly explosive gas. Hydrogen gas is diatomic, meaning each gas molecule is composed of a pair of atoms.

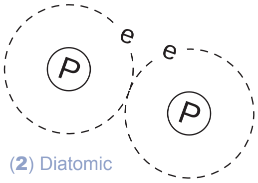
In the Proton Source Department, Jim Lackey, Chuck Schmidt, Bob Webber and their colleagues take this simple substance and do what Fermilab always does best. They bust it apart, transforming the hydrogen gas into a beam of protons traveling at nearly the speed of light, with an energy of 8 GeV (billion electron volts).

"You could say the process of getting the protons from the hydrogen is quite inefficient," Schmidt said. "The number of useful protons we produce is about one part in a million of what we put in at the start."

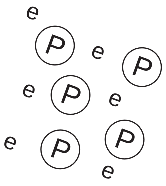


(**1**) Hydrogen

When jolted by sufficient voltage, the hydrogen atoms come apart and rearrange themselves to form ions with positive or negative charges. A gas dissociating this way in an electric field is called a plasma. The process is analogous to chemical dissociation, where a molecule in a solution separates into charged ions (for example, NaCl into Na+ and Cl—). The plasma, or ionized gas, conducts electricity, just as the ionized NaCl solution conducts electricity, and just as the gas inside a fluorescent light bulb conducts electricity.



(**2**) Diatomic Hydrogen gas



(**3**) Plasma

In forming the plasma, some hydrogen atoms lose electrons and a few gain electrons. Those gaining a single electron become H-minus ions (H—), which are extracted from the plasma by positive voltages, formed into a beam of particles and accelerated to nearly the speed of light by the end of the proton production process.

The Cockcroft-Walton pre-accelerator, resembling a gleaming gizmo from a 1930's Flash Gordon serial, generates 750,000 volts to start the ions on their journey through the vacuum passageway. The oldest of the Lab's accelerators, the Cockcroft-Walton must be manually grounded for maintenance by a technician wielding an 18-foot wooden pole; yet it represents one of the Lab's earliest uses of fiber optics for transmitting computer information from equipment at high voltages where conventional wire can't be used.

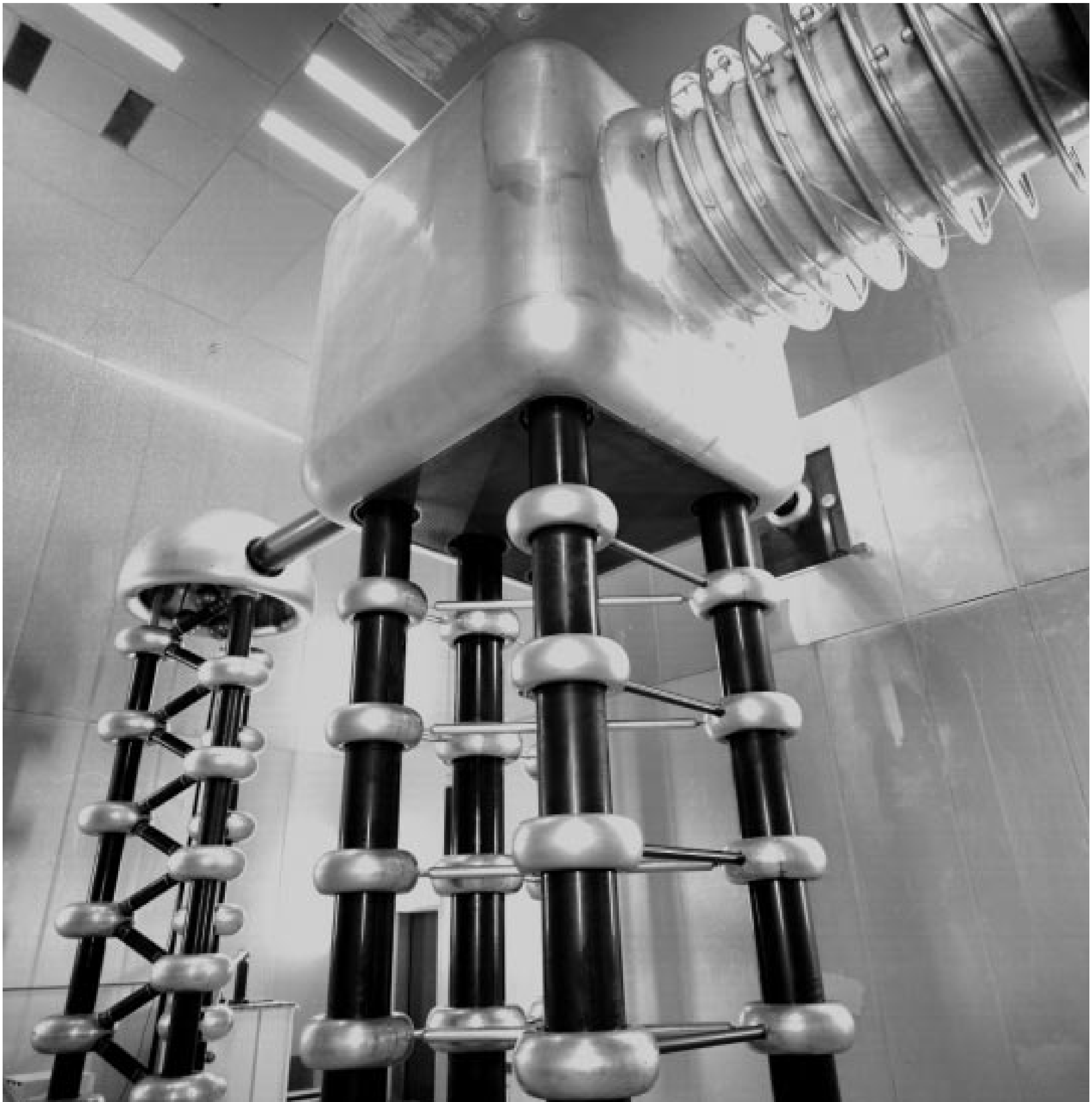
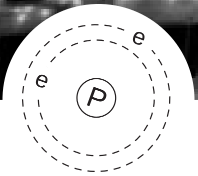
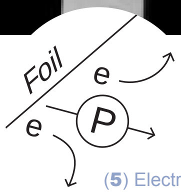


Photo by Reidar Hahn

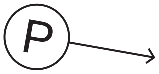
The Cockcroft-Walton.



(**4**) H-minus



(**5**) Electrons stripped



(**6**) Protons

The Path From Hydrogen Atom to Proton Beam

A hydrogen atom (**1**) consists of an electron and a proton. Hydrogen gas is diatomic (**2**). When jolted by sufficient voltage, diatomic hydrogen gas molecules dissociate to form a plasma (**3**) of positively and negatively charged ions. After the H-minus ions (**4**) are extracted, the Cockcroft-Walton starts them on their journey through the Linac. At the entrance to the Booster, the electrons are stripped off the ions (**5**), leaving just protons to be accelerated through the system (**6**).

Photos by Reidar Hahn

Chuck Schmidt invites you into the Cockcroft-Walton pre-accelerator, beginning the journey from hydrogen gas to proton beam. Jim Wendt and Ray Hren do some fine-tuning inside the apparatus.

Bob Webber at the Booster accelerator, where H-minus ions are transformed into protons and accelerated to nearly the speed of light.

When the H-minus ions leave the Cockcroft-Walton, they are moving at about 0.04 c, or four percent of the speed of light (about 7,440 miles per second). The Linac, or Linear Accelerator, immediately increases that speed by subjecting the ions to alternating voltages in a series of radiofrequency cavities spread out at increasing intervals along a 500-foot straightaway corridor.

Household voltage from Commonwealth Edison changes polarity 60 times per second. The early accelerating voltages experienced by the beam in the Linac change polarity 200 million times per second (200 megahertz, or MHz). The high frequency power comes from a large vacuum-tube amplifier called triodes, originally developed in the Cold War era of the 1950s for the NORAD (North American Air Defense) system. The final RF cavity frequency is 800 MHz, powered by even bigger amplifiers called klystrons.

Because opposite charges attract, the negatively-charged hydrogen ions must always see a positive charge attracting them to their next destination, whether it's the far end of the RF cavity they've just entered, or the entrance to the next RF cavity along the route. Their travel time from cavity to cavity is a constant five billionths of a second while their speed increases down the corridor. Since their speed is increasing and the frequency is a constant, the cavities must be spaced farther and farther apart.

The ions leave the Linac at 0.7 c (about 130,200 miles per second), with an energy of 400 MeV (million electron volts), more than 500 times their energy when exiting the Cockcroft-Walton. The Linac sends the ions into a transport line connected to the Booster accelerator, which cashes in on the ions' negative charge and produces the payoff for not accelerating positively-charged protons at the start of the process.

Starting with a beam of protons, which Fermilab did until 1977-78, meant filling the Booster's 1,600-foot circumference with only a single turn of particles for the best operation. The switch to what's called "H-minus injection" immediately improved the Booster's intensity by allowing additional turns of protons from the negatively-charged hydrogen ions to be stacked on top of a proton beam already circulating in the machine.

At the entrance to the Booster, a magnet diverts the ions to a carbon foil 1.5 microns thick (0.0015 millimeters), weighing 300 micrograms per square centimeter (that's 300 millionths of a gram, or about 10^{-7} ounces), mounted on a fork-like frame.

"Here's where the magic happens," Webber said.

The foil is so thin, it would flutter away if you breathed on it. But it's substantial enough to strip off the electrons from the hydrogen ions, leaving just the nuclei—protons—to be merged with the protons previously injected into the machine. The injection process continues until the Booster has as many protons as it can handle, or as many as it needs.

The Booster then accelerates the new proton beam in standard synchrotron manner—RF cavities imparting energy, with frequencies ranging from 38 MHz to 53 MHz; magnets bending the beam around the circular track for multiple passes through the RF cavities. The speed of the beam increases from .7 c to nearly the speed of light, the largest proportional speed boost of Fermilab's three synchrotrons (the Booster, Main Injector, and Tevatron). When the energy reaches 8 GeV, the Booster transfers the proton beam to the Main Injector; from there, the beam goes to antiproton production, to the Tevatron, and to fixed target experiments.

"This whole acceleration process in the Booster," Webber said, "lasts 1/30 of a second."

That 1/30 of a second, the origin of the discoveries and the wonder, is part of the everyday routine at Fermilab, as unassuming as a morning cup of coffee. And equally essential.