The Life and Legacy of Helen Thom Edwards

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All over the world new discoveries are made, new inventions are created, and new innovations are brought to life. A lot of times we never see what happens behind the scenes and we often take for granted the many hearts and hands that go into bringing these creations to life. If you are a physicist or in any STEM related field, you may be familiar with particles accelerators. Particle accelerators are machines that accelerate elementary particles to high energies, producing beams that can be used for a variety of research purposes and come in many shapes and sizes. Prior to 2009, the most powerful particle accelerator was the *Tevatron*. One of the driving forces behind, inside, on top of, and quite frankly all around the innovation of this extraordinary device was none other than Helen Thom Edwards. Helen Edwards was a particle accelerator physicist whose life's work was spent creating, learning, and influencing others about the world and the impact of particle accelerators. Helen Edwards and her extraordinary curiosity and instinct for innovation has led to great contributions to the scientific world.

Early Life

Helen Thom Edwards was born Helen Thom to her stockbroker father, Edgar Thom, and mother, Mary Thom on May 27, 1936. Thom and her family lived in Pontiac, Michigan for the beginning of her life. She was the youngest of five children with three older sisters and an older brother. Her siblings were Milner, Catherine, Mary, and Anne. Out of all her siblings, she seemed to be the only one that took an interest in science. From a young age, she remembers her distaste for reading and spelling though she enjoyed the wonders of nature, biology and the natural sciences. From the start, she was always a technical person. It was when her family moved to a ranch near Metamora, Michigan where she started to develop a love for nature, the outdoors, and animals. One could say that she was a curious child. Thom attended the Kingswood School in Cranbrook, Michigan until 1950, then she began attending the Madeira School for girls in McLean, Virginia. When her older sisters Mary and Anne were seniors, she began attending Madeira School her sophomore year. It was at Madeira that she started taking on positions that would reflect the titles she would possess later in life. While attending Madeira, she was the vice-head of student government and fire chief. Her superiors believed she brought "wisdom and mature judgement to her work" on the Student Governing Board. She took an interest in sports and was a member of the varsity hockey, basketball, and horseback riding teams. It seemed like she quite enjoyed working with her hands whenever she could. Many of her teachers spoke highly of her. To them, it was obvious that she possessed "unusual ability in mathematics and science, showing delightful originality and great intellectual curiosity". She was "conscientious and dependable." When it was time for college, Thom applied to Cornell University in Ithaca, New York, Duke University in Durham, North Carolina and Massachusetts Institution of Technology (MIT) in Cambridge Massachusetts. Due to her brilliance and enthusiasm for her work, she had no real trouble pursuing higher education. She had her heart set on attending MIT, but because of her father's concerns, that did not seem like a possibility. Her parents were

Figure 1: Helen Edwards, Madeira School Class of 1953

worried about her because they believed that she was not prepared to be far away from home. Unbeknownst to them at the time, she had dyslexia, a learning disorder that affects one's ability to read, spell, write, and speak. Dyslexia was not a learning disorder that was well known at the time, so to her family, her difficulties in reading and related subjects were a major concern. Despite her learning disorder, she was a brilliant young girl with a curiosity that would take her to outstanding places in life. With her father's worriedness and concerns in mind, she would continue her higher education close to home. In the spring of 1953, she graduated from The Madeira School and attended Cornell University in the fall.

Higher Education

At Cornell, Thom studied physics, naturally, due to her interests. Her love for the natural sciences, always working with her hands, and her endless curiosity made physics the ideal subject for her to study. In 1957, she graduated with a bachelor’s degree in physics. After earning her degree, she wanted to continue the path of becoming a physicist. With the talents and skills that she possessed, there is no doubt that she could have continued to earn her doctorate immediately. Due to the climate at the time, male graduates could continue to earn their doctorate directly after undergraduate, while women had to earn their master’s degrees first. She did not let this stand in her way and decided to continue pursuing her education through the physics master's program. She started working under Cornell's cosmic ray physicist, Kenneth Greisen, who specialized in the development of cosmic rays While working on a machine in the basement of the Laboratory of Nuclear Studies, she met Donald Edwards, her future partner, who was an instructor at the university and was pursuing his doctorate. Fittingly to her life, they met while she was hard at work. The two later got married in 1963 and their relationship continued throughout their lives and careers. While earning her masters, some faculty at Cornell started to take note of the brilliance and talent that she possessed. She graduated with her degree in 1963 and continued to pursue her doctorate. Thom, now known as Edwards, then began working in the Laboratory of Nuclear Studies with Boyce McDaniel as her thesis advisor. Her passion for particle accelerator physics developed while she was working under McDaniel’s supervision. Her drive and care for her work continued to shine through for the three years that she worked on her doctorate and was offered a position to continue working at Cornell. By this time, her talent was well recognized, and she completed her doctorate in 1966.

Career

Prior to 1966, Cornell started building a 10 billion electron volt (GeV) synchrotron. A synchrotron is a circular particle accelerator, in which particle beams travel around a fixed closed loop. This construction was led by Robert R. Wilson, a physics professor and the director of the Laboratory of Nuclear studies. At the time of earning her doctorate, the accelerator had been under construction and was just beginning to come under operation. Her talents had been recognized by many, including Robert Wilson, leading up to the completion of her doctorate. Wilson offered her a position managing the steps to put the 10 GeV synchrotron into operation. While working on the synchrotron, her knack for leadership was on the forefront. Through this position she was able to demonstrate her ability to manage others well. Edwards and Wilson were similar when it came to the talent and dedication they had towards physics that oftentimes resulted in clashing ideals. Nonetheless, they were still able to get the job done. Not long after the first beam circulated in the

synchrotron in 1967, Wilson accepted a position to be the director of the National Accelerator Laboratory in Batavia, Illinois. This was later renamed Fermi National Accelerator Laboratory after physicist Enrico Fermi. She continued working at Cornell for the next two years until Wilson offered both her and her husband, Donald, a position to work at the National Accelerator Laboratory (Fermilab). Although these two may have butted heads when it came to working, one thing was for certain and that was the fact that they worked well together. Since Cornell did not allow husbands and wives to both be full time employees, it made sense for them to leave New York and start a new life in Illinois. Come 1970, both Edwards and her husband started working on the Main Ring accelerator under the supervision of Wilson. Edwards oversaw the commissioning of the accelerator and began working as the head of the Booster Group that brought the laboratory's 8 GeV Booster into operation. Edwards and the team at Fermilab worked hard on the accelerator for the next year until the first beam was accelerated to 7 GeV, in June of 1971. There was still more work to come in the following year to get the machine to reach its full and expected potential of 200 GeV. At times, Edwards and her team worked 7 days a week and 24 hours a day to stabilize the beams being accelerated through the machine. A few days prior to the beam reaching its full potential, Edwards believed that the instability of the beam after reaching a certain voltage was due to a problem in the rise of current and the bending of the magnets. The night before the beam was accelerated Edwards and her husband had spent all night fixing the problem. On March 1st, the beam in the accelerator had reached its design potential and celebration later ensued. Not shortly after in 1972, a new project began, which would not only change Edwards' life, but also make large contributions to the world of science in terms of superconductivity and atomic physics.

The Tevatron

In 1967, Wilson had proposed the use of superconducting magnets to double the energy of the main accelerator, referred to as the Energy Doubler or Tevatron. In 1971, when the main ring was in operation, talks of putting the Doubler into motion began to resurface. In 1972, work on the Doubler began. In 1975, an experiment on studying beam transport through superconducting magnets that Edwards was working on influenced where 16 of the Doubler magnets were set up. This location was named B-12. At B-12 many experiments, tests, and prototyping took place. In the following years tests were conducted, structures were built, and the Doubler was slowly coming together. Around 1977, Wilson tried to obtain more funding to build the Doubler by writing a letter to the Secretary of Energy. In his letter, he talked about the lack of support of Fermilab and threatened to resign as director of the laboratory if expectations for the lab did not change. Around this time, a powerful group within Fermilab was starting to develop. Wilson had failed to include many of his particle accelerator scientists from participation in the Doubler. A small group, which went by the name of Underground Parameter Committee (UPC), was created to promote the involvement of the accelerator scientists in the Doubler's design. This group consisted of none other than Edwards herself, her husband Donald, and nine other accelerator scientists. A year later, in 1978, Wilson again threatened to resign as director in order to receive more funding and this time the Fermilab Board of Trustees accepted his resignation. Leon Lederman then became the laboratory's second director and Edwards was put in charge of

designing the Doubler's new design report. Edwards worked continuously with other scientists for the next few years to get the design for the new machine in order. During the process of integrating the accelerator community with the design of the Doubler, it was apparent that good management and leadership needed to be present to resolve previous issues that arose and allow a smooth transition into the completion of the Doubler. In 1980, Edwards became the Deputy Head of the accelerator division. Edwards had an “unrelenting determination to get things done and a penchant for coloring outside the lines when it came to solving problems.” Her qualities made her an excellent candidate for the position she held and allowed her to maneuver well through the development of the project. She was, unsurprisingly, very intellectual about the scientific world and oftentimes relied on her own intellect when it came to solving problems. One could say she had a talent for recognizing other talent. She knew just where and when to place the right in order to carry out projects successfully. She was always very encouraging and appreciative of the work of others. Throughout the entirety of the project, her presence was felt. Later, in July of 1983, the Doubler reached its design goal. After many bumps in the road and years of hard work, the Doubler was finally complete. Lederman recounted that Edwards contributed to almost every aspect of the Doubler including, "superconducting magnet production, magnet testing, cryogenics, radio frequency, vacuum systems, beam diagnostics, controls, lattice design and orbit theory, magnet parameter acceptance criteria, magnet correction elements, power supplies, supporting documentation and cost control, quench protection, extraction system, injection systems and beam transport, beam-abort systems, radiation protection, and installation." She was a force to be reckoned with and if something needed to be done, she was able to do it. During the construction and development of the accelerator the application of superconductivity was an important aspect in which Edwards was engaged. This period allowed for the expansion of superconductivity and its application in other fields such as medicine, including magnetic resonance imaging (MRI). From this machine, the top quark was discovered, and the tau neutrino was observed. From her work on the Tevatron and the applications that allowed the device to be operated, Edwards was awarded The USPAS Prize for Achievement in Accelerator Physics & Technology in 1985, granted an Ernest Lawrence Award in 1986, and received a MacArthur Foundation Fellowship in 1988, which she put towards in the support of basic research education. In 1989, she was also awarded with the National Medal of Technology by President George Bush. The Tevatron was officially turned off in 2011 due to the

Figure 2: Helen Edwards and laboratory director, Leon Lederman, late at night waiting on experimental results, 1983

Figure 3: Helen Edwards signs a document indicating the final installation of the superconducting magnet, 1983

completion of the Large Hadron Collider, a more powerful accelerator. The Tevatron was shut down when Edwards, alongside her husband and Lederman, pushed the button to turn off the machine.

Superconducting Super Collider

Edwards continued working at Fermilab until 1989, when the plans for a Superconducting Super Collider (SSC) was put in place. The SSC was planned to be the world's largest and most energetic accelerator. Due to the magnitude and large scale of the project, many states wanted to be the destination of the machine's construction. Many wanted the location to be Fermilab, but in order for the laboratory to be considered for the constructor of the project, four people had to agree to go wherever the decided destination was. Amidst the group was Edwards. Once meetings and plans were conducted, it was decided that the construction location for the SSC would be Texas. In 1989, Edwards and her husband packed up their belongings and moved from Illinois to Texas. In Texas, Edwards was the Head Associate Director of the Superconducting Division. The climate in Texas became turbulent very quickly. There were many debates about the costs of the project, along with the contrasts of another development underway, the International Space Station. Edwards was not too fond of the idea of the SSC due to it being a large upscaled version of the previously constructed Tevatron. She was more concerned with the world of exploring and innovation that was fueled by her unequivocal curiosity. The project simply did not interest her, but nonetheless she stuck with it because she had signed an agreement to be the technical director of the project. Tensions in Texas arose due to her lack of popularity by the men that she worked with. Nonetheless, she stayed until she fulfilled her duties of creating a design report and estimating the cost of production. Around this time, a friend of Edwards's from Germany, introduced her to the idea of building a new accelerator using superconductivity for the accelerating structure as well as the magnets. Of course, Edwards could not resist the opportunity to put her unprecedented knowledge into action. The fruits of her curiosity and need for innovation was ripe. In 1981, once she was finished with her designated task for the SSC, she and her husband, once again, packed up and headed off to Hamburg, Germany. In 1982, the SSC project was cancelled, due to the high costs and several other factors.

Deutsches Elektronen Synchrotron

Prior to fully relocating to Germany, Edwards had made several trips to the Deutsches Elektronen Synchrotron (DESY) and assisted the team in the construction and operation of the proton ring accelerator for their HERA (Hadron-Electron Ring Accelerator) project. Her knowledge and experience on working on the Tevatron was of value to the completion of the project. Around 1992, DESY became the driving force in TESLA (Te-V Superconducting Linear Accelerator) studies. TESLA was the effort of building a superconducting electron linear accelerator (linac). Edwards became the first project manager of the TESLA test facility (TTF). The TTF was a research and development site for studying the properties of superconductivity in future linear colliders. While Edwards worked at the TTF, there was great progress made in superconducting radiofrequency (SRF) acceleration**.** A device used to create a high-quality electron beam, called the RF, gun was also created from this facility. Many of the possibilities that happened at TTF was, in part, due to the collaboration DESY had with Fermilab. Thankfully, it was Edwards who was able to convince Fermilab to join the project. From the research and

development that happened at TTF, DESY created their first free-electron laser (FLASH). FLASH used superconducting accelerator technology to propel the electrons to the required high energy. This work also led to the development of the x-ray free electron laser (XFEL). The new insights of exploration and innovation was of great interest to her and she spent many long and hard-working years contributing and expanding on her knowledge of superconductivity. One thing about Edwards was that she always saw a new opportunity for innovation whenever she could. Once the majority of the research was conducted, she saw the opportunity at Fermilab to take many of the technology that was developed at DESY to build a linac at Fermilab. These efforts were what led Fermilab to adopt the development for superconducting accelerator structures. By 2000, Edwards and her husband were back at Fermilab working on their linear accelerator. She believed that the accelerator was important to the future of Fermilab. At Fermilab she was the head of a research group developing a photoinjector for the projected linear collider, called the A0 Photoinjector project. Her work and collaboration between DESY and Fermilab continued on for many years. No matter where she was, the passion and drive that she had for innovation never died. The efforts and years of working at DESY has led to many significant developments in the studies of superconductivity and its applications. In 2001, Edwards and her husband were endowed with a chair in accelerator physics at Cornell.

Graduate Student

One of the ways that Edwards continued her contribution to particle accelerator physics was by taking on a graduate student from Rutgers University. While working on the A0 project at Fermilab, Edwards was the supervisor of graduate student Timothy Koeth. Under Edwards' supervision, Koeth led two accelerator projects. Koeth was able to bring the first high-gradient superconducting RF cavity at Fermilab into operation as well as performing the first experimental demonstration of a longitudinal-transverse phase space exchange. Since receiving his doctorate, Koeth has kept the spirit of Edwards alive through his work on Neutron Imaging, Far Ultraviolet Neutron Detector, the Betatron Project, the UMER Nonlinear Optics Project, High Resolution Gamma Ray Spectroscopy, and the Mystery of the German Uranium Cube. He, too, has also been a graduate advisor to several students, to which he passed down the knowledge he gained through his work with Edwards and particle physics. Edwards taught him valuable skills that he will carry with him through his endeavors in the field of particle accelerators as well as life.

Figure 4: Helen Edwards and her graduate student Timothy Koeth, 2006

Life

When Edwards was not working, which was not often, she took an interest in the wonders that the world had to offer. She was always encompassed some way or another in the natural world.

Figure 5: Helen Edwards with the 15-pound canoe she constructed in her home

Even though her enjoyment for science and nature led her to her career, she always had the same excitement and adventurous spirit when it came to her personal life. She had an interest in any and everything. One of her interests was gardening. When she and her husband moved to Illinois, she had the opportunity to get out into nature and try her hand at something new. It is no secret that she enjoyed working with her hands. In an exchange that happened between her and her husband, he claimed if she was able to successfully grow a garden, he would do all the cooking. Let's just say that he did a lot of cooking during their marriage. It is fair to say that underestimating Helen Edwards was never an option, in her personal or professional life. To no surprise, no matter where she went, she was always working with her hands and building things. This makes sense seeing that she was an inventor and her spirit of curiosity never stopped. While living in Montana, she had the urge to build a canoe. The canoe was constructed on the second story of her home. After several months of working on the device, she had successfully built a 15 pound, fully functioning canoe. Her love for exploring and nature also took her on exciting adventures. She travelled to many places including Sierra Nevada and Owens Valley for backpacking, as well as all the way to the Arctic and Antarctic. No adventure was too big or too small for her to embark on. No matter where she was, she never stopped working. Her passion for the field and her love for the natural world motivated her to contribute her life to discovering the wonders that the world had to offer. Edwards unfortunately passed on June 21, 2016 at the age of 80. Her death was the result of cancer, initially chondrosarcoma, that metastasized despite surgery. She was dedicated to her work until the very end, so much so that just two days prior to her passing, she worked diligently with other scientists remotely.

When it comes to the world of particle accelerator physics, there is no doubt that there have been many influential and outstanding people that have contributed to the field. One of these individuals is most notably Helen Thom Edwards. Edwards was a driven physicist who dedicated her life to her work on particle accelerators. From a young age, her fascination with the natural world led her to pursuing her multiple degrees and joining projects that have significantly impacted the field of physics, as well as others. She was known for her dedication and diligence as she never gave up and always followed through with her assigned tasks and projects. Her collaborative and curious spirit opened new doors and led to timeless discoveries. Edwards always impressed those around her and served as an inspiration to many, including Timothy Koeth, the participants of the A0 Photoinjector project, and her peers at DESY. From the Tevatron to the work at the Deutsches Elektronen Synchrotron, Edwards was always front and center, overseeing the design and construction of these, among several other, scientific devices. Her contributions to these projects led to their resulting success and her work never went unrecognized as she received several awards and honors throughout her lifetime. The Fermi National Accelerator Laboratory would not have been the same without Edward’s passionate and continuous, outstanding work. There is no doubt

that Helen Edwards has earned the title as one of the most influential female scientists of the 20th century.

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