70 Years of Collaboration, Celebration, and Acceleration

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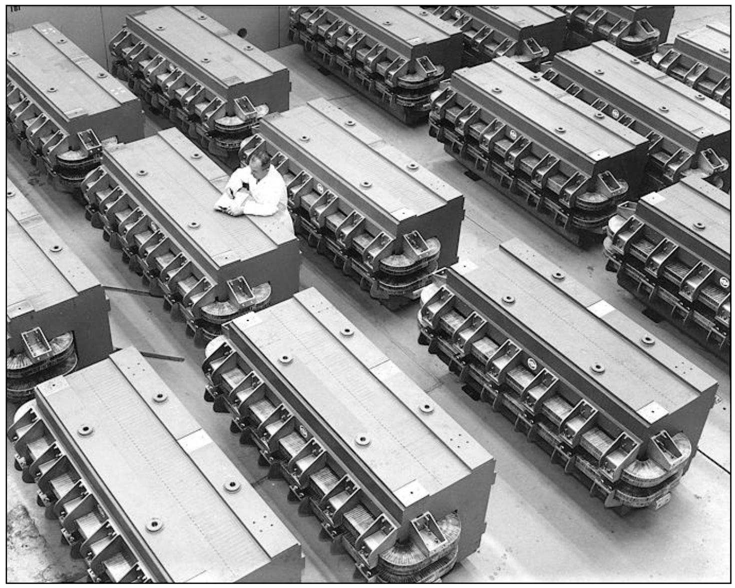

Magnets for the Alternating Gradient Synchrotron (AGS) at Brookhaven Lab awaiting installation into the accelerator ring tunnel in 1958. The AGS became home to three of Brookhaven's seven Nobel Prize-winning discoveries.

In an iconic picture taken in 1958 at Brookhaven National Laboratory, a man scribbles notes with his pen and paper while sitting on a series of magnets; he was working on his physics project, both figuratively and literally. To me, this old photograph encompasses the very nature of scientific discovery. The singularity of the working scientist represents the singularity of his thoughts-the only problem on his mind was his experiment. Like his scientific query, he stood alone, using the stillness of the magnets to help him focus. Just as these magnets were soon to be installed in Brookhaven National Laboratory's Alternating Gradient Synchrotron, the scientist's ideas and experiments would infiltrate BNL's premises as well, becoming a part of its legacy. The level of dedication seen in this photograph is how our greatest discoveries are made. Just like the scientist and his magnets, it's all in plain black and white.

The scientist in the picture, along with many others, would soon transform these magnets into Brookhaven National Laboratory's (BNL) Alternating Gradient Synchrotron (AGS). The AGS is a particle accelerator that was designed by BNL scientists to allow protons to reach energies that had never before been achievable. From 1960 to 1968, BNL's AGS was the highest energy accelerator in the world [8]. The AGS is based on the concept of alternating gradient focusing. Particles are accelerated by 240 magnets as their field gradients are "alternated inward and outward" allowing the particles to be focused in both the horizontal and vertical plane simultaneously [1]. These magnets are helical and proton spin is controlled in the AGS by a three tesla snake magnet [7]. The

AGS's brilliant design has earned BNL physicists three Nobel Prizes and now functions as the injector for BNL's Relativistic Heavy Ion Collider (RHIC) [10].

The creation of the Alternating Gradient Synchrotron led to three ground-breaking discoveries in the field of physics. In 1962, three Columbia students went to the most powerful particle accelerator in the world to determine if another "ghostlike" particle similar to the electron-neutrino existed. They used the AGS to accelerate protons and crash them into a target made of 5,000 tons of metal from old battleships. These scientists discovered the muon-neutrino, a particle that passes through everything, and later won the 1988 Nobel Prize in Physics thanks to BNL's AGS. This experiment was the first ever use of the neutrino beam and laid the foundation for countless discoveries behind it [5].

Another ground-breaking discovery occurred in 1976 when an MIT research team discovered the J/psi particle using Brookhaven's AGS. Researcher Samuel Ting accelerated protons to crash into a target, causing the protons to break apart so that the resulting particles could be measured by detectors. Ting discovered the J/psi particle, which was later found to be made up of a charmed quark and its antiquark, thus proving the charmed quark's existence. Ting and his team won the Nobel Prize in 1976 for their work on the AGS and brought well-deserved recognition to Brookhaven National Laboratory [4].

The discoveries continued in 1980 when two Princeton students, James Cronin and Val Fitch, used the AGS to prove one of the fundamental aspects of physics. They designed an experiment to show that two different particles decayed into different products. However, they were shocked to see that they had discovered an example of CP violation, or deviation from CP symmetry, when different particles both decayed into two pi mesons. This result sent a ripple through the world of physics, as it had shown an example of a flaw in the central theory that the universe is symmetrical. Many experiments have been done since Cronin and Fitch's discovery, but none have been able to explain the miraculous results that were found using BNL's Alternating Gradient Synchrotron [2].

Since the AGS's creation in 1960, it has been upgraded to commensurate with physics' evolution and to keep up with the demands of advancing scientific research. In 1997, the AGS was upgraded to include a partial wave analysis program that allows identification of states beyond the quark model, or states with gluonic degrees of freedom [3, 11]. Recently, at the 2016 RHIC & AGS Users' Meeting, scientists gathered to discuss future plans for BNL's synchrotrons. Their visions for the future included the possible creation of an electron-ion collider (EIC), which would accelerate electrons to collide with heavy ions and create high- resolution images of the gluons that hold all matter together [6]. The ability to unravel the secrets behind these essential particles would be a colossal achievement for the world of physics.

BNL also strives to bring science beyond scientists, through outreach to those who wouldn't traditionally have access to it. I can personally attest to its success from my own experience. In second grade, I went on a field trip with my class to Brookhaven National Laboratory, and we were given the opportunity to explore interactive science stations. I remember this trip clearly because it was not simply another field trip to me; it was the start of my love for science. I am eternally grateful to BNL for helping me discover my passion at such a young age. Not only does BNL target children, but it is also focusing on the inclusion of more women and other minorities in the STEM fields [6]. Through increased education and scientific literacy, BNL hopes to expand the diversity of scientists not only in its own labs, but throughout the country.

The creation of BNL's Alternating Gradient Synchrotron in 1960 changed the world of physics forever. The theoretical and practical applications of its many discoveries are wide- reaching. BNL's scientists have created a vehicle for enormous advancements in the fields of medicine, spectroscopy, and computer technology [9]. When I look to the future and think about all of the great feats BNL will conquer, I see that same scientist sitting and working on his project from 1958. However, I now see what wasn't in the photograph: a team of researchers beside him, discussing, planning, and collaborating. Our greatest achievements occur when we collaborate. Like a world traveler, an idea can trek from one mind to the next, gaining context and momentum with each careful thought it is exposed to. Collaboration must continue among physicists, mathematicians, and engineers to determine the next steps in the creation of a new particle accelerator, of new technologies, and of new discoveries. Men and women of all races and backgrounds have the power to advance our knowledge of the physical world to heights that never seemed possible. As we accomplish these great feats, we will always remember the humble scientists who paved the way before us. And behind each humble scientist, we will remember the laboratory, Brookhaven National Laboratory.

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