The history of physics has been driven by the insatiable human need to understand the nature of the world. Isaac Newton laid down the ground rules of the universe with his model of classical physics, but continuing discoveries over the next few centuries chipped away at his model, revealing the universe to be something stranger than we had imagined. The subatomic world is a strange one indeed, known to us primarily through the use and refinement of particle accelerators and colliders, culminating with the Large Hadron Collider. These devices have altered the course of history and their continued use contributes to our ever-expanding knowledge. However, this knowledge comes with risk, and not all are willing to pay the price. The ethics of specific scientific advances have received much less attention than the advances themselves; this area remains largely unexplored. In the rush to make progress and learn more, physicists have rarely stopped to question whether they should, instead focusing on if they could.

Particle accelerators have been useful in uncovering the secrets of the atom, but they have also made contributions to other areas of science. Cyclotrons yielded early access to radioactive isotopes, useful for diagnoses and treatments in the medical field. They also contributed to the discovery and use of Carbon-14, which is useful in organic chemistry and carbon dating. Even industrial manufacturing and production make use of isotopes from accelerators. Finally, while
they were not strictly necessary in the discovery and refinement of nuclear fission, they were they chosen tool that led to nuclear arms and energy.¹

However, despite all these social and scientific advances, there are still some who fear the use of modern accelerators. Recently, there was some protest to the use of the Large Hadron Collider (LHC) for fear that its use might result in the creation of a black hole that would consume the earth. While these fears turned out to be unfounded, they were based in the precautionary principle, summarized thus: “when human activities may lead to morally unacceptable harm that is scientifically plausible but uncertain, actions shall be taken to avoid or diminish that harm.”² However, the precautionary principle has its own detractors, who claim that either its application is unjustified, or that it is imprecise and incoherent.³ Regardless, it raises an interesting question that lies at the heart of the matter: what are the acceptable risks in the name of science, and do the potential benefits justify them?

**Particle Accelerator Development**

The history of particle accelerators begins in the early twentieth century. Ernest Lawrence and M. Stanley Livingston’s cyclotron was the first to accelerate protons to 1 MeV of kinetic energy,⁴ while Cockcroft and Walton’s electrostatic accelerator was the first to artificially split the atomic nucleus.⁵ From the beginning, particle acceleration was a risky, mysterious

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⁴ Wilson, “US Particle Accelerators at Age 50,” 87.

endeavor: Lawrence built his device without any real analysis of the beams’ focusing conditions, while later storage rings were built without a full understanding of the needed stability conditions. The risks were largely unknown but comparatively inconsequential, and the rewards were great. These experiments in 1932 paved the way for the glut of larger and more powerful accelerators that would follow.

Another early type of accelerator was the synchrotron, which mainly used protons and rose to prominence in the post-war era. This new, larger accelerator promised deeper insights into the subnuclear structure, but even the physicists in charge were uncertain exactly what would happen when it was activated: “there is not the slightest doubt the electrons in the electron beam will also do many things we as yet do not even suspect,” they said. Granted, they did not predict such large-scale calamities as those associated with the LHC, but the fact remains that they marched boldly forward, even in the absence of total scientific certainty. Their audacity paid off in the discovery of even more new subatomic particles, including the antiproton, antineutron, the meson, and its associated quarks. However, despite the advances being made in the field of subatomic physics, further knowledge always remained just out of reach. The discovery of the aforementioned particles, as well as the fact that protons and neutrons can be broken down further, spurred physicists to develop yet more powerful accelerators. When electron bullets are accelerated in a circular manner, as in cyclotrons and synchrotrons, they lose some energy as radiation. In order to boost them to even greater speeds and energies, it was necessary to develop a much larger linear accelerator.

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Linear accelerators, like the one eventually established at Stanford, tended to utilize small, lightweight electrons, rather than the comparatively heavier protons. By accelerating them down a straight path, they were able to achieve extremely high speeds and energies, approaching the speed of light. The proposal to move forward with research was initially mired in scientific and political controversy, although it was focused more on the immense cost of ever-more powerful accelerators, rather than fears of the unknown.9 Spurred by the scientific arms race against the Soviet Union, the question of whether or not we could took precedence over whether or not we should, and the project continued. Indeed, the only significant fears of this era were of foreign superiority or hostility, and the long-term dangers of nuclear reactors,10 both of which were only tangentially related to the accelerators themselves.

**The Large Hadron Collider**

The history of particle accelerators and colliders culminates in the huge, circular, superconducting devices we currently utilize. Colliders like these differ from simple earlier accelerators in that they direct their high-energy particle beams at other high-energy particle beams, rather than at a fixed target. The resulting collisions would theoretically simulate conditions similar to those during and immediately after the big bang, creating new brief-lived particles and energies. The most famous (or infamous) of these new devices is the Large Hadron Collider. (A hadron is a particle family that encompasses protons and neutrons, and it is on these particles that the LHC focuses.) Although the LHC would later draw ire and fear, it was initially met with open arms; a committee of physicists urged the US to join the European project for the

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sheer sake of scientific advancement and knowledge.\textsuperscript{11} The potential knowledge to be gained would indeed be worth investigating: Higgs bosons would help to explain mass, supersymmetric particles would be a boon towards formulating a unified field theory, and energy anomalies could demonstrate the existence of extra dimensions.\textsuperscript{12}

However, the intense energy associated with these tiny collisions carries with it also the possibility of creating “density isomers” resulting from stable abnormal nuclear states; this possibility was recognized as early as 1971.\textsuperscript{13} For all intents and purposes, such nuclear matter would essentially be a tiny black hole, and it is onto this sensational idea that critics most fervently attached. Those involved were not seriously worried about the possibility, for two main reasons. First, the earth is constantly bombarded by solar energies and cosmic rays that are much more powerful than the LHC (which would not be operating at peak capacity anyway.)\textsuperscript{14} These energies are also theoretically capable of creating tiny black holes, and not once in its multi-billion year lifespan has a black hole harmed the earth.\textsuperscript{15} Second, any black hole that was formed, however unlikely, would almost immediately dissipate into nothingness, ultimately leaving no trace and causing no harm.\textsuperscript{16} It is interesting to note that some scientists were actually \textit{hoping} that the LHC would create a black hole that they could study,\textsuperscript{17} so confident were they in


\textsuperscript{13} Joseph I. Kapusta, "Accelerator Disaster Scenarios, the Unabomber, and Scientific Risks," \textit{Physics In Perspective} 10, no. 2 (June 2008): 169.


their knowledge that any black hole would immediately evaporate and pose no threat. Another worrying possibility was that the collider would create particles called strangelets, which could pose similar dangers. This fear, too, was acknowledged as possible but unlikely; the electrical charge of any created strangelets would theoretically inhibit fusion or repel them from nearby matter entirely.\(^{18}\)

Nevertheless, skeptics remained fearful. In 2008, Walter L. Wagner and Luis Sancho filed a lawsuit against CERN, seeking a restraining order until they (CERN) filed an environmental safety assessment, deferring again to the Precautionary Principle.\(^{19}\) Wagner had filed similar suits in 1999 and 2000 against the Relativistic Heavy Ion Collider; they were dismissed. Similarly, Richard A. Posner’s 2004 book, *Catastrophe: Risk and Response* sought to bring public attention to global disasters, including those possibly resulting from high-energy particle physics experiments.

**Conclusion**

The apparent uncertainty about the outcome of the LHC experiments, coupled with the decision to move forward in defiance of critics’ fears, is not without precedent. As mentioned previously, Lawrence was fumbling in the dark with his cyclotron, and the scientists who built the first synchrotron were not sure exactly what would happen when it would be used, but they conducted their experiments anyway. Again, these examples are somewhat low-risk, so a much more fitting comparison is the decision to detonate the hydrogen bomb. At the time, there were concerns that the detonation of such a large weapon could start a chain reaction that would ignite

\(^{18}\) Kapusta, “Accelerator Disaster Scenarios, the Unabomber, and Scientific Risks,” 176.

the atmosphere and destroy all life on earth. The experts at Los Alamos, like their modern counterparts at CERN, had calculated that the fears were ungrounded and the risk was negligible\(^2\) and proceeded with their experiment. The doubters were proved wrong and science marched on.

History has demonstrated that physicists are no strangers to risky experiments. Although they usually have a deep theoretical understanding of their field, it is impossible to know more without conducting experiments. However, it is also impossible to know entirely what exactly will happen in the process of doing so. From the simple cyclotron to the mighty Large Hadron Collider, particle accelerators have played a crucial role in our ever-increasing knowledge of theoretical physics. Their continued use appears to be safe, despite protests to the contrary from fearful critics. Nevertheless, we should be mindful of the risks and weigh them against the potential gains in the future.

Bibliography


