# INTRODUCTION

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The Fermilab Industrial Affiliates are a group of more than thirty companies with interests in the research and development work underway at Fermilab. The principal motivation for the Affiliates was to provide a mechanism for ready access to this work, as well as to the work of physicists from seventy or so universities who work at the accelerator. Our experience has been that the Affiliate program's major value is as a forum for communication between the academic and industrial research communities.

## Why Affiliates?

The Affiliates do represent an effort on the part of Fermilab to address a larger responsibility and need of science. Basic research in such an exotic subject as particle physics is essentially a cultural activity; however, it is a public trust and the substantial expenditures are justified in terms of long-range benefits to society. The Affiliates aim at exploring ways to hasten and even institutionalize the benefit processes. In addition, modern science is intimately dependent on industrial technology which in turn is beholden to earlier basic science. This interdependency must be understood and fostered. It generates a non-linearity such that advances in the present decade exceed those of the previous three or four decades.

A central feature of the Affiliates annual meeting has been a round table on some important topic. Earlier round tables covered university-industry relations and supercomputers. This year the theme was "Industry and Large Scientific Projects - Particle Accelerators and Projections into the Future: A Super Accelerator." The theme was designed to explore industrial attitudes toward large basic research projects at the leading edge of technology.

Over the last year there has been intense consideration of the possibility of an accelerator twenty times the size of the Fermilab Energy Saver. Serious discussions were initiated in the summer of 1982 and these culminated in a recommendation by the High Energy Physics Advisory Panel in July of 1983. This was to construct, as the highest priority for the field, a proton-proton collider with each superconducting ring having an energy of 20 TeV. Now this did get the attention of the U.S. Department of Energy and it has the enormous enthusiasm of the high-energy physicists. It is called SSC or Superconducting Super Accelerator.

## Need For An SSC: Particle Physics Primer

The confluence of several factors served to stimulate interest in the project. First, operation of the Fermilab Energy Saver has emphatically demonstrated that a superconducting accelerator will work. Recent monumental physics discoveries at CERN have shown that experiments can be performed with colliding proton beams at an energy approaching that suggested for a super accelerator. Most important, the veil has begun to lift on the physics of the future and a host of questions lie waiting for a super accelerator.

At first glance, the present picture of basic matter seems almost perfect. The "standard model" of matter has twelve objects divided up into two classes called quarks and leptons. There are six quarks and six leptons that come in three generations. Now the notion is that these twelve objects are the simplest objects that can be found. These particles are supposed to be structureless. They have no insides; they can't be taken apart. So they're literally point objects. That doesn't mean they don't have rich and differentiating properties. They have masses, they have electric charges, and they are subject to forces in different ways. Everything in the universe can be made by combining these objects together. For example, neutrons and protons are made by combining three quarks, while atoms are made by attaching leptons to the protons and neutrons built up from the quarks. Atoms make molecules, and molecules make Industrial Affiliates and all sorts of other things.

There are also four forces: the electromagnetic force, the weak force, the strong force, and gravity. They have different strengths, they have different ranges, and they are enormously different. The forces are described in terms of fields, and the fields are quantized. The quanta of the fields are the force carriers. Characteristically, there's a great mathematical similarity in the description of these forces. The force carrier for electromagnetism is the photon or quantum of light. In the weak force, there are three force carriers: the $W^+$, $W^-$, and the $Z^o$. For the strong force, there are eight carriers, called gluons. There isn't a quantum theory of gravity yet, so not much is known about the carriers, nevertheless they are named; they are called gravitons. A strong motivation exists for trying to unify these forces, i.e., for finding an underlying concept out of which the apparently diverse forces emerge as artifacts of our peculiar situation as observers. Indeed, some success has been achieved in a joining of the weak and electromagnetic forces.

Now this simple picture can almost fit on a T-shirt (soon to be available from Friends of Fermilab). This encapsulates all the published data from all the world's accelerator laboratories for the last 3,000 years. This picture, of course, is highly symbolic, but nevertheless, it tells everything there is to know about all the data.

This picture works! In particular, it predicted the masses of the $W^+$, $W^-$, and $Z^o$ to three significant figures. The picture has also made it possible to establish strong links between the origin of the universe and the physics of these fundamental particles.

## The Open Questions

But there are open questions when a closer look is taken at the standard picture. Some are intuitive, but some are very disturbing. These questions are a roadblock to progress. The number of publications in the theoretical journals is zooming up because there's no data to limit speculation. What are some of the problems? A dramatic illustration is the $Z^o$. All the force carriers should have zero mass. Indeed, this is true of the photon and the gluons. However, the $Z^o$ has a very heavy mass. That's been a puzzle. A gentleman named Higgs found a theoretical mechanism for generating that mass. This leads fundamentally to a deeper question, the problem of the origin of mass. All of the theoretical speculations on how the Higgs mechanism might be observed experimentally seem to point to a region of collision energies of the order of 1-2 TeV in the center of mass. There are a lot of Higgs-related speculations that go under the names of supersymmetry and technicolor, which all point to hypothesized objects with masses somewhere in the region of 1 TeV. Another issue is why are there three generations of quarks and leptons? There's a large and seemingly arbitrary set of parameters in the standard model. The quark and lepton masses aren't really understood. Are the quarks and leptons <u>really</u> point objects? There are a lot of speculations about possible substructure of quarks; maybe there are little people running around inside quarks, or something simpler than quarks which would give fewer basic objects. If so, the place to start looking is around 1 TeV. The energy domain at which the SSC will operate is designed to address these questions and any new ones that lie in the future.

## The SSC

The possibility of accelerators an order of magnitude larger than the Energy Saver have been considered since the original Fermilab machine went into operation. By 1975 there were serious discussions concerning a Very Big Accelerator or VBA. High-energy physics leaders met in New Orleans that year to map out a ten-year plan to study the possibilities. In 1976, the International Union of Pure and Applied Physics established a committee for future accelerators. International workshops were held at Fermilab in 1978 and Les Diablerets in Europe in 1979. These discussions were capped with the concrete proposal at Snowmass in 1982 to build a superconducting super collider.

By its nature an accelerator twenty times the size of Fermilab will require industrial participation. Industrial involvement is necessary because of the large scale; something on the order of 10,000 magnets have to be built. However, the scope of participation needs discussion. Clearly industry will provide the materials but that's not what we meet about here. Industrial participation on a deep and very technical level is desirable if it serves technology transfer. How to do this without increasing costs and risks is not clear.

In the following discussion, we have assembled a group of industrial experts to address these issues. We have also included representatives from Japan and West Germany in order to explore any differences in attitudes towards these problems.

We at Fermilab have found the round table dramatically illuminating. We hope that publication of the record will help many more in industry, government, the universities, and the national laboratories to understand the factors that influence the character of industrial participation in large-scale science projects in general and the super accelerator project in particular.

If you find this round table interesting, you may want to consider membership in the Fermilab Industrial Affiliates. More details are given on page 127.

*[Editor's Note: The round table was organized with the help of Dick Lundy and Dick Carrigan. Dick Carrigan edited the proceedings; Rene Donaldson, Cathy Gianneschi, and Sue Grommes prepared the publication. The cover was designed by Angela Gonzales.]*