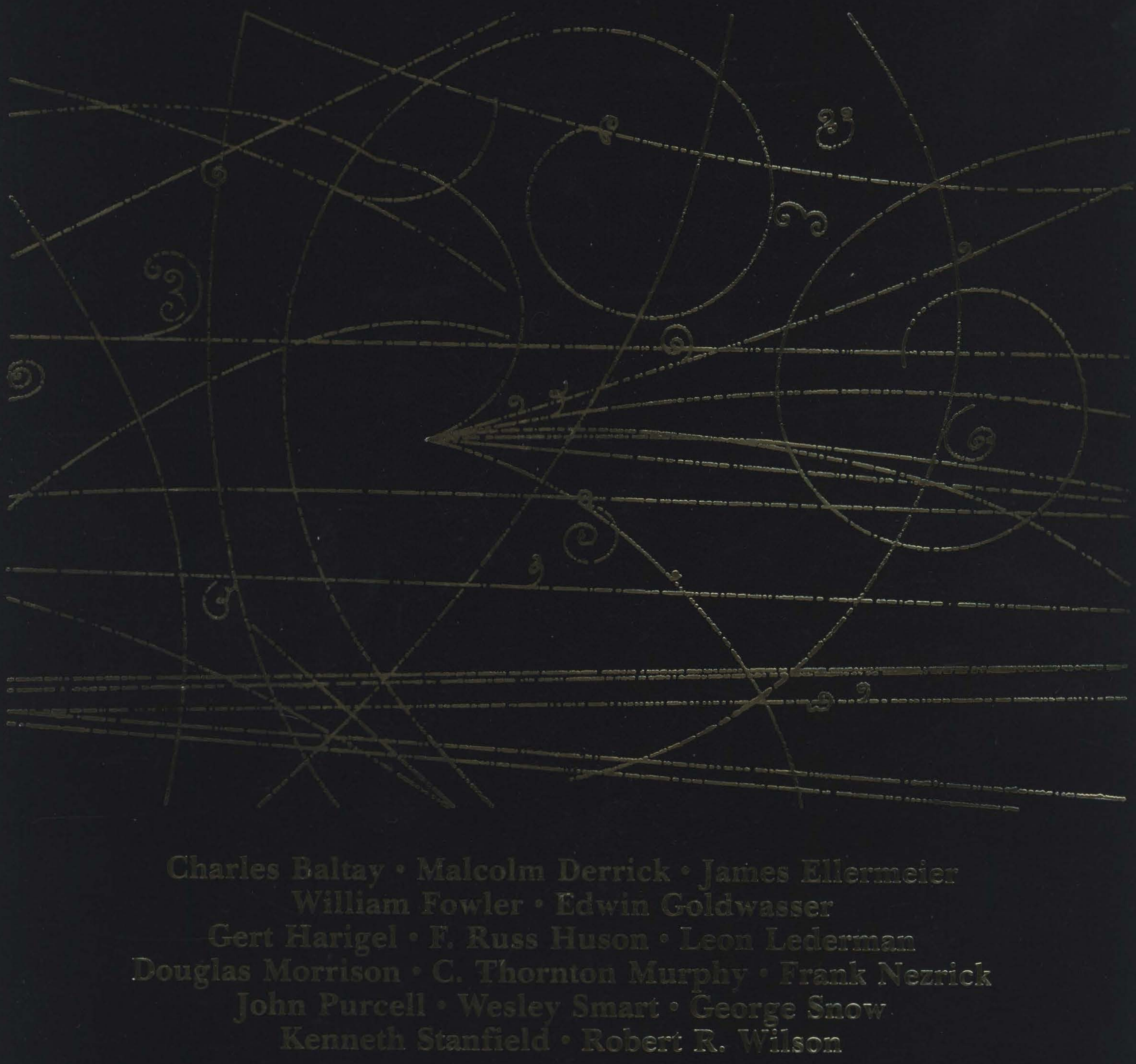
Reflections on the Fifteen Foot Bubble Chamber at Fermilab



Charles Baltay • Malcolm Derrick • James Ellermeier
William Fowler • Edwin Goldwasser
Gert Harigel • F. Russ Huson • Leon Lederman
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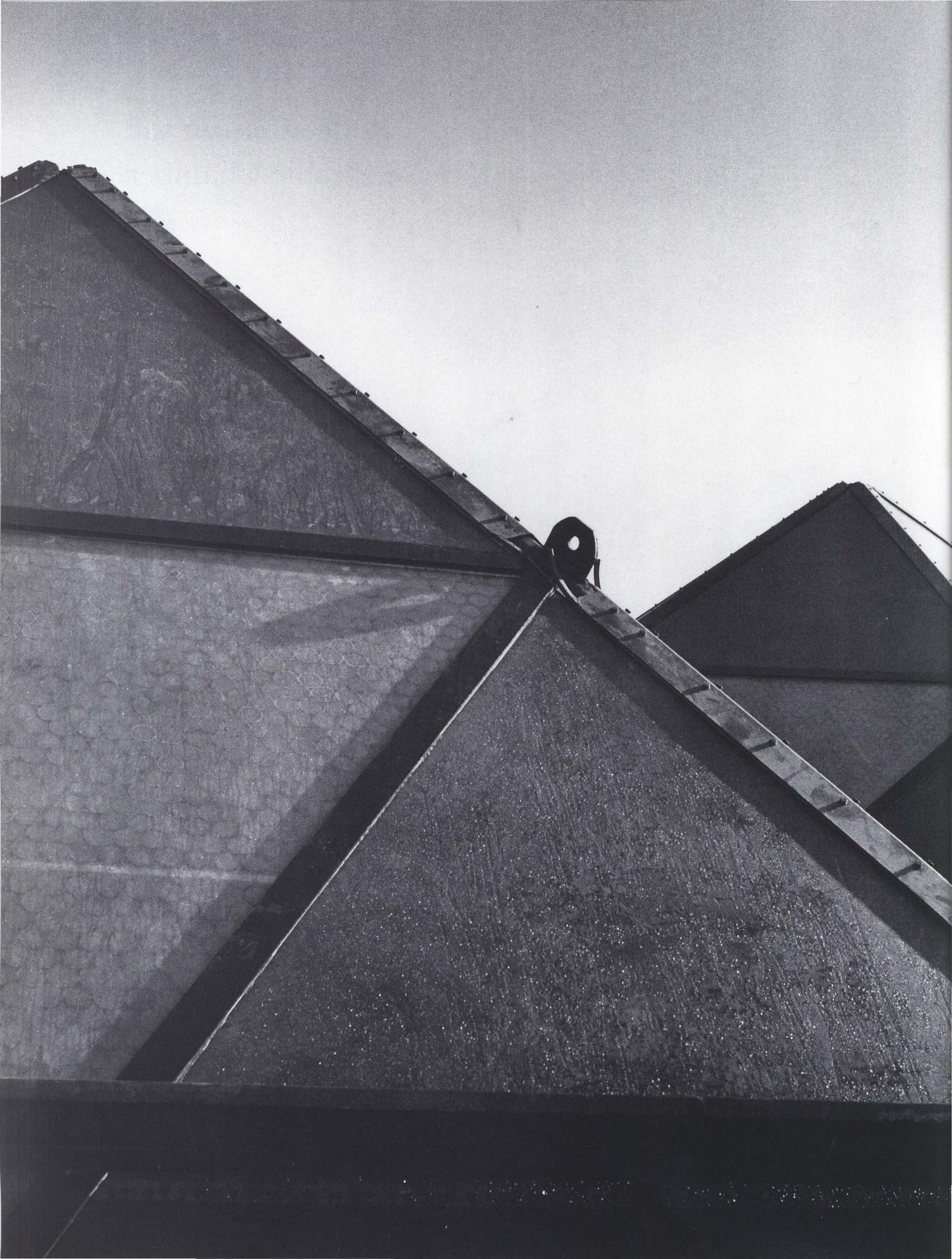
Mark W. Bodnarczuk, Editor

Reflections on the
15 Foot Bubble Chamber



Reflections on the 15 Foot Bubble Chamber at Fermilab

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Fermi National Accelerator Laboratory
Batavia, Illinois

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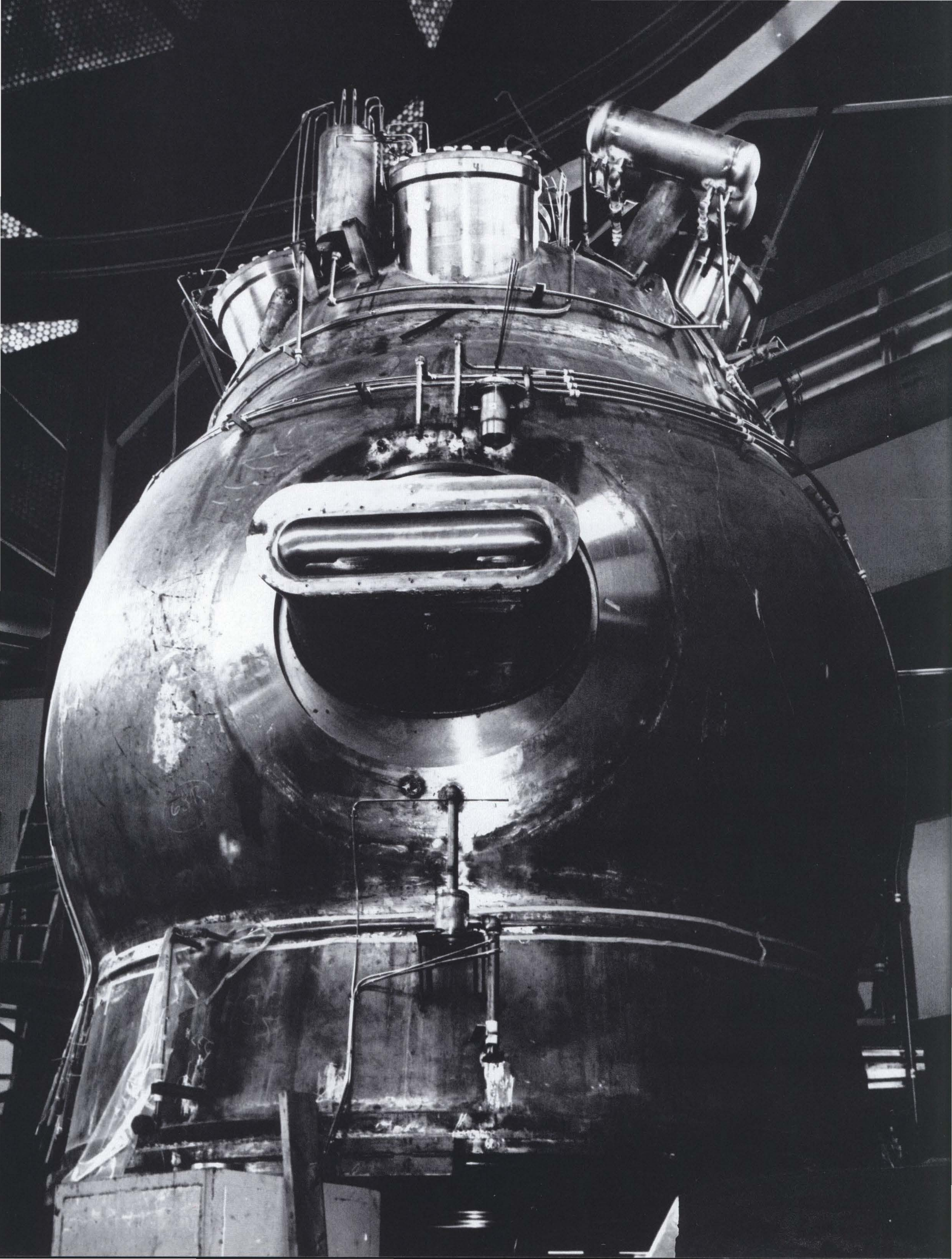

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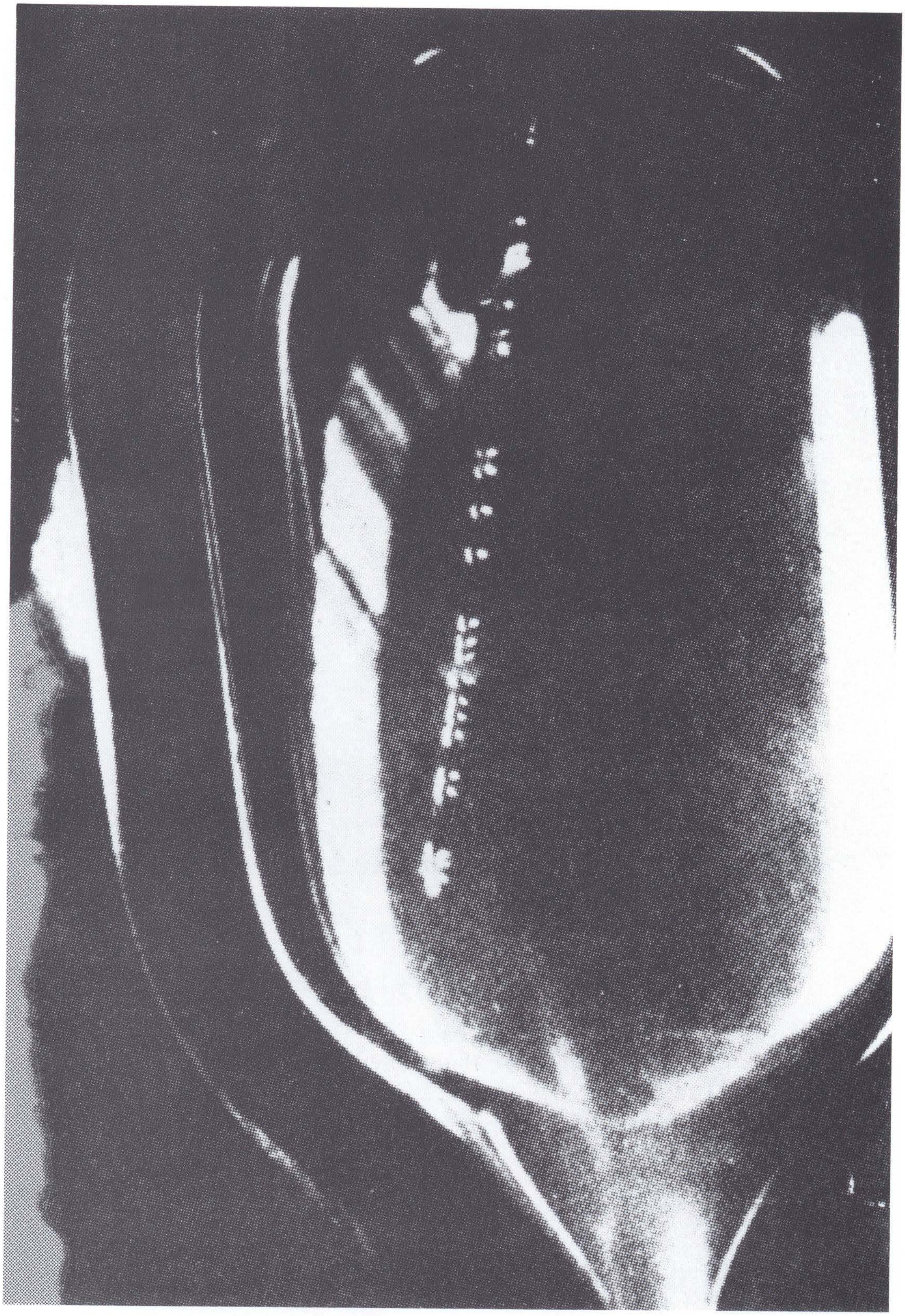
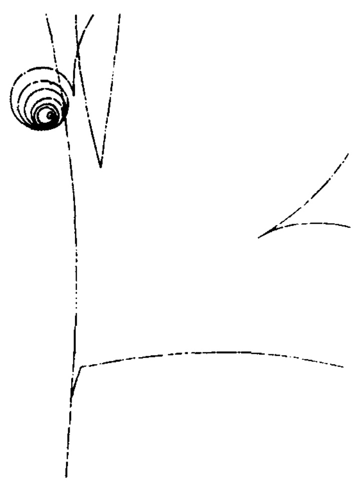


Introduction

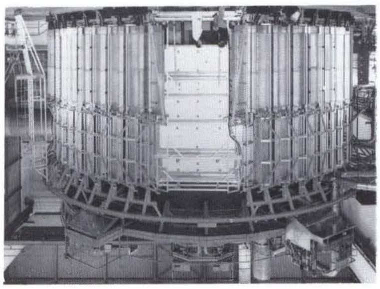
Mark Bodnarczuk
Fermilab

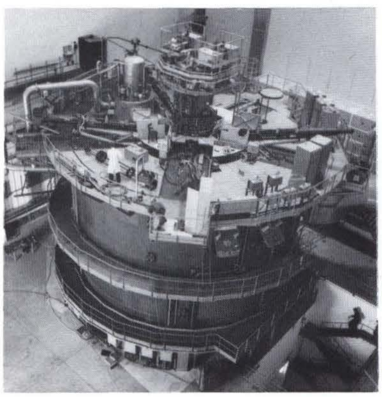
One of the most difficult aspects of high-energy physics is the pace at which change occurs as the discipline is advanced by theory, experiment, and technological break-throughs. Perhaps one of the best examples of this is the discovery of the transistor followed closely by the advent of the digital computer. Today, if a data acquisition system takes more than 1-2 years from the design phase to implementation, not only will the components probably be available commercially in off-the-shelf products, but the technology may even be out of date. Even some theories seem to come and go almost faddishly. But one aspect of high-energy physics that tends to change more slowly is the general types of detectors used in experiments. In fact, one gets an interesting view of the development of particle physics by analyzing the trends in the types of detectors that have been used and how older-style detectors have been retired as more sophisticated devices, using new technologies, have been used to revise and reconfigure experiments.

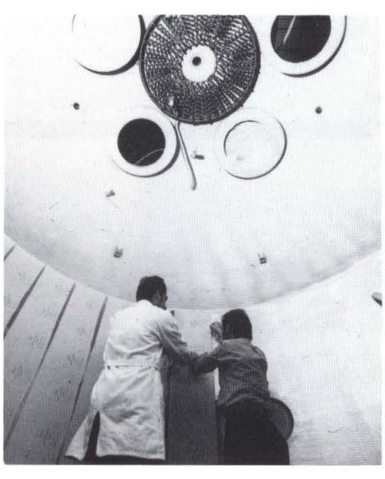
Over the last 25 years, high-energy physics detectors have been classified in a number of different ways, with two of the most widely used categories being electronic counter and bubble chambers apparatus. Ever since Donald A. Glaser developed the first bubble chamber in 1952 at the University of Michigan, bubble chambers have been used successfully in myriad high-energy physics experiments including the discovery of the ρ, η, Ξ^0 and Ω^- particles.



Glaser's original bubble chamber was a transparent glass device which was only a few inches across. He knew that if he placed a pure liquid in a sealed container he could superheat the liquid beyond its normal boiling point and the liquid would not boil. Once superheated, boiling could be triggered by something penetrating into the liquid in the vessel. Glaser calculated that the energy that charged particles would deposit in the superheated liquid while penetrating and ionizing the chamber would be enough to trigger a trail of boiling bubbles along the trajectory of the particle. He further surmised that these bubble events could be observed with the naked eye through the glass chamber or permanently recorded by taking



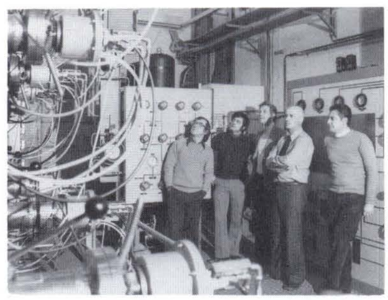




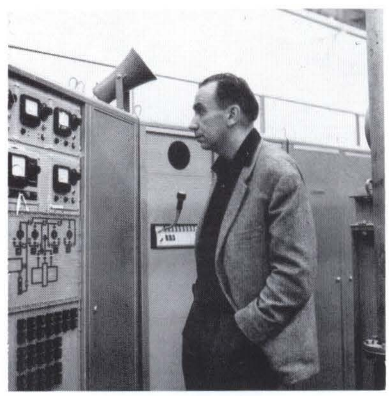
a photograph of the interaction in the chamber before the bubbles dispersed. Glaser later won the Nobel Prize for this innovative work.

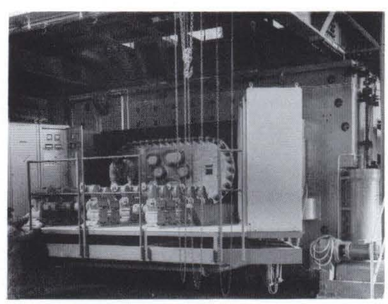
Shortly after this first design proved successful, bubble chambers were constructed from metal-glass combinations and the photographing was done via optical glass windows built into the chamber wall. Eventually a group at Berkeley, headed by Luis Alvarez, extrapolated this technology, moving from a chamber that was only a few inches across to one that was six feet long. Although an extension of Glaser's idea, Alvarez's chamber involved many new innovations, some of which permanently changed the field of particle physics. As well as providing a clear advance in physics potential due to the much larger fiducial volume in which events could occur, the large bubble chamber was a clear and prophetic departure from the kind of "table-top" experiments that Glaser's device typified. Whereas Glaser was directly involved in *all* phases of the design, construction, and operation of his bubble chamber (in the tradition of experimenters like Boyle, Torricelli or Newton), Alvarez assembled a *team* composed of structural, cryogenic, and operations engineers plus other technical personnel in order to carry his experiments through to completion. This was complemented by physicists and film scanners to process the data once it was accumulated. Alvarez's collaborative efforts and the idea of assembling an experimental support *team,* many of whom were not physicists, was a prototype of all subsequent large bubble chamber runs at high-energy physics laboratories like Fermilab, Brookhaven, SLAC, and CERN. Even more interesting is the proto-typic role that these experiments have played in describing the type of support structure necessary to carry out today's large electronic counter experiments. Alvarez's bubble chamber changed the way particle physicists designed and configured their experiments, establishing an outstanding potential for high-energy physics research at Lawrence Berkeley Laboratory (LBL) and Stanford Linear Accelerator Center. Alvarez won the Nobel Prize for this work.

Fermilab's 15 Foot Bubble Chamber is the last in a long developmental line of *large* bubble chambers in the United States and in Europe. The following are only a few highlights of this illustrious history. On the Continent, CERN began work on the 2 Meter Hydrogen Bubble Chamber in 1959. The 2 meter chamber ran successfully at both the Proton Synchrotron and the Super Proton Synchrotron. The Gargamelle Bubble Chamber was installed at CERN in 1969 and was used to probe the nucleus by inelastic scattering with a neutrino beam, providing evidence for quarks as the constituents of nucleons, and later, conclusive evidence for the existence of neutral currents. Other big bubble chambers across the Atlantic included CERN's Big European Bubble Chamber (BEBC), and the Mirabelle Bubble Chamber designed at Saclay, France, for use at the 70-GeV accelerator at Serpukhov, U.S.S.R. In the United States, Tom Fields and a group from Northwestern University developed the first bubble chamber in a superconducting magnet at Argonne National Laboratory (ANL), leading the way for Gale Pewitt and his colleagues who developed the 12-ft. bubble chamber, also at ANL. The 7-ft. bubble chamber at Brookhaven (BNL) also produced interesting physics and new discoveries for a considerable period of time.



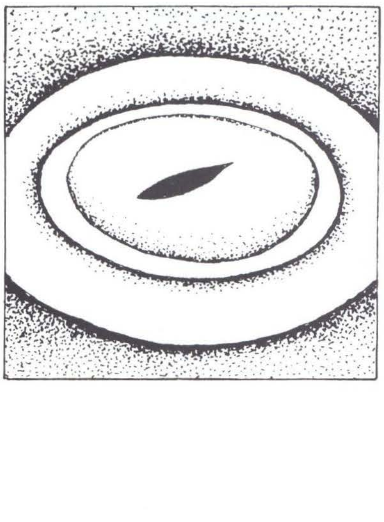
In this tradition, Fermilab's 15 Foot Bubble Chamber is the last large cryogenic bubble chamber to operate anywhere in the world and its decommissioning marks the end of an era. The first tracks were recorded on September 29, 1973, in conjunction with experiment E-28, and the last tracks were recorded on February 1, 1988, in conjunction with experiment E-632. In all, there were 17 approved and completed experiments performed with the chamber, covering a wide variety of physics topics. There were also two experiments carried out with the 15 Foot Bubble Chamber Magnet, using cosmic rays rather than beams from the accelerator. In his "Fifteen Foot Fest" presentation, Charles Baltay (Yale University) described some of the unique aspects of the 15 Foot Bubble Chamber, namely the ability to see electrons and strange particles (K^0 and Λ^0) and the ability to detect hadrons and the fine details of decay vertices. The chamber provided unique contributions to neutrino physics, including charm production by neutrinos, rare neutral current processes, and tests of QCD through hadronic production by neutrinos. A complete list of all experiments performed with the 15 Foot Bubble Chamber and a list of all physics publications to date that have been based upon data taken with the 15 Foot Bubble Chamber are listed in Appendix A.

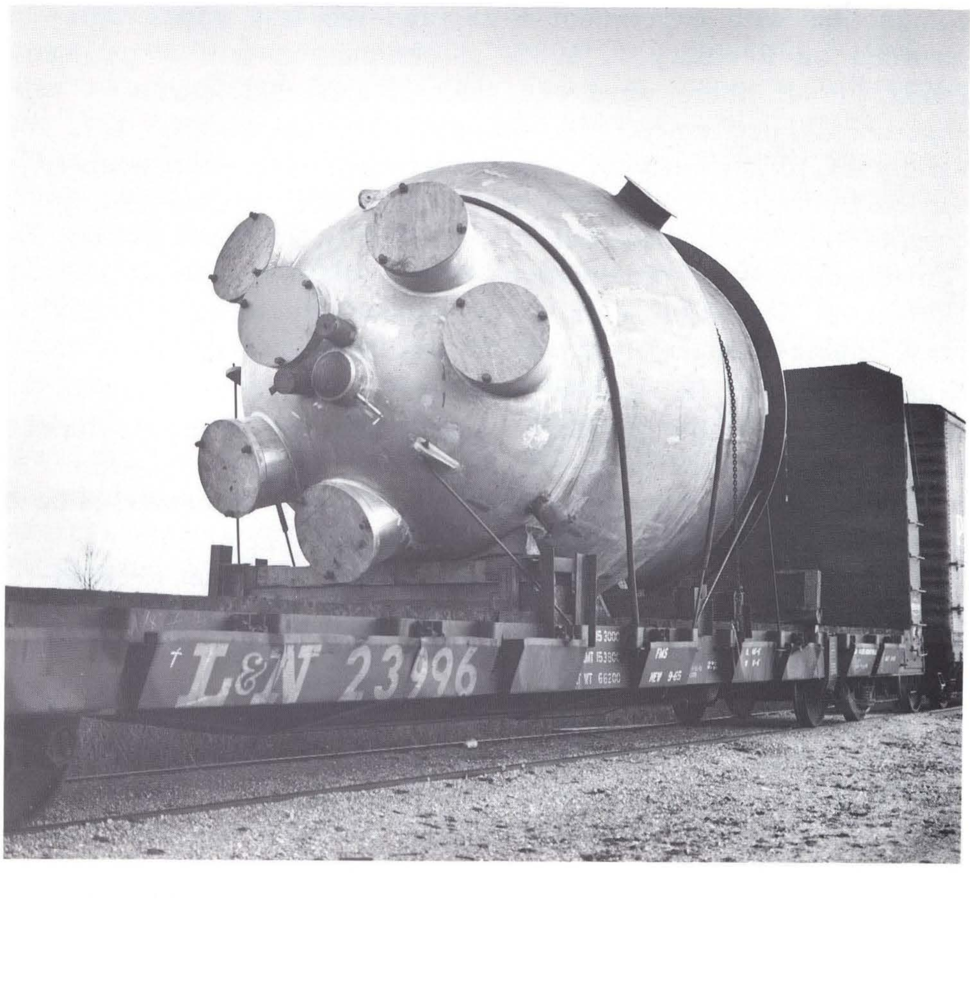




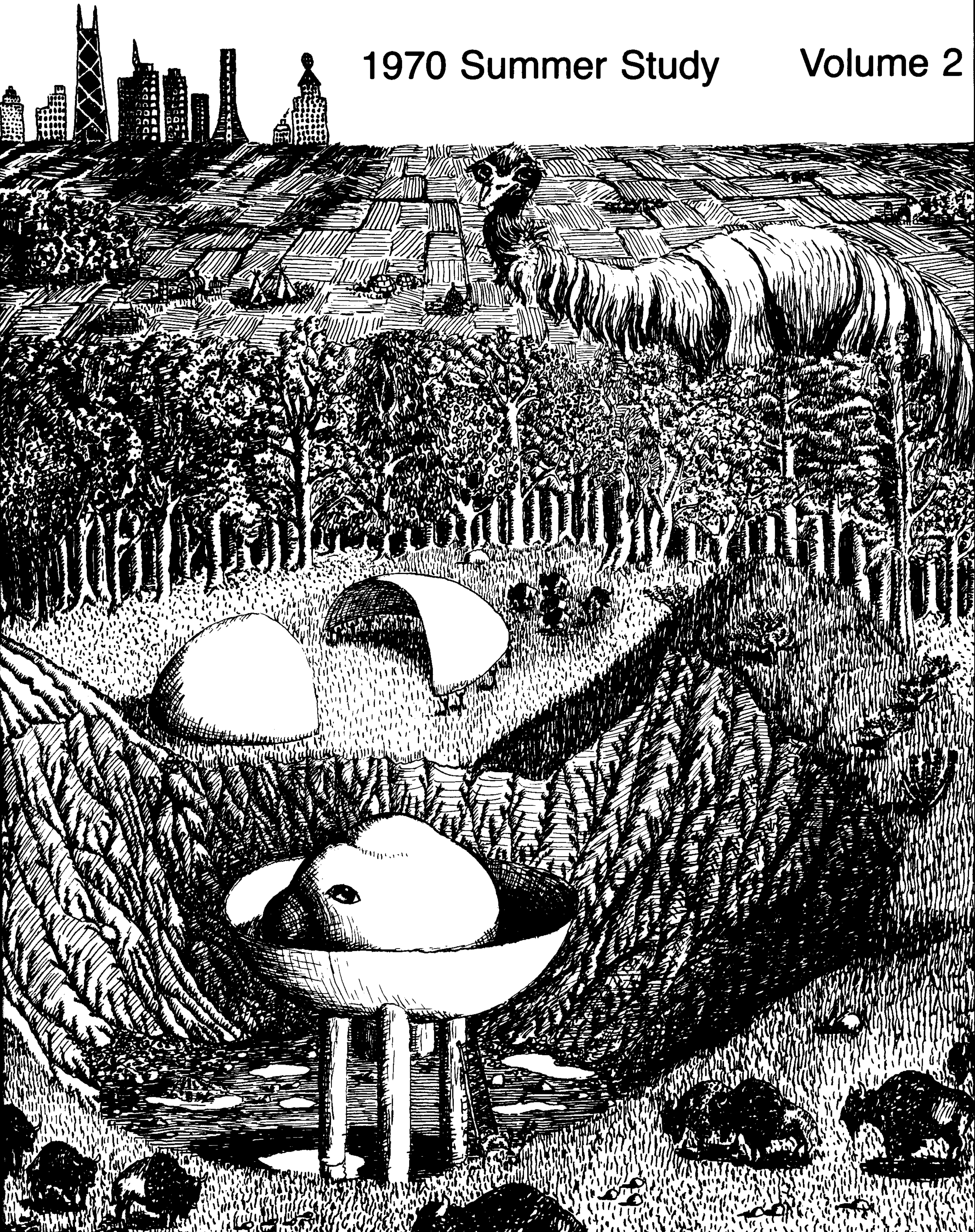
In addition to the short presentations given by each of the speakers at the 15 Foot Fest, Fest Chairman Thornton Murphy read a number of telexes that had been sent by those who could not attend the Fest, but wanted to thank those who were intimately involved in the chamber's success. These can be found in Appendix B. G. Myatt (Oxford) said of the 15 Foot Bubble Chamber, "The important scientific results which have come out of previous runs, and which will come over the next few years from analysis of the final run, are a fitting tribute to the success of the 15 Foot Bubble Chamber program." Echoing what seemed to be an international sentiment that the decommissioning of the 15 Foot Bubble Chamber had indeed marked the end of an era, Paul Hernandez (LBL) remarked that, "After 34 years of bubble chamber connections and the last 16 or so with the 15 Foot, I see the 15 Foot Bubble Chamber as the Jewel in the Crown..."

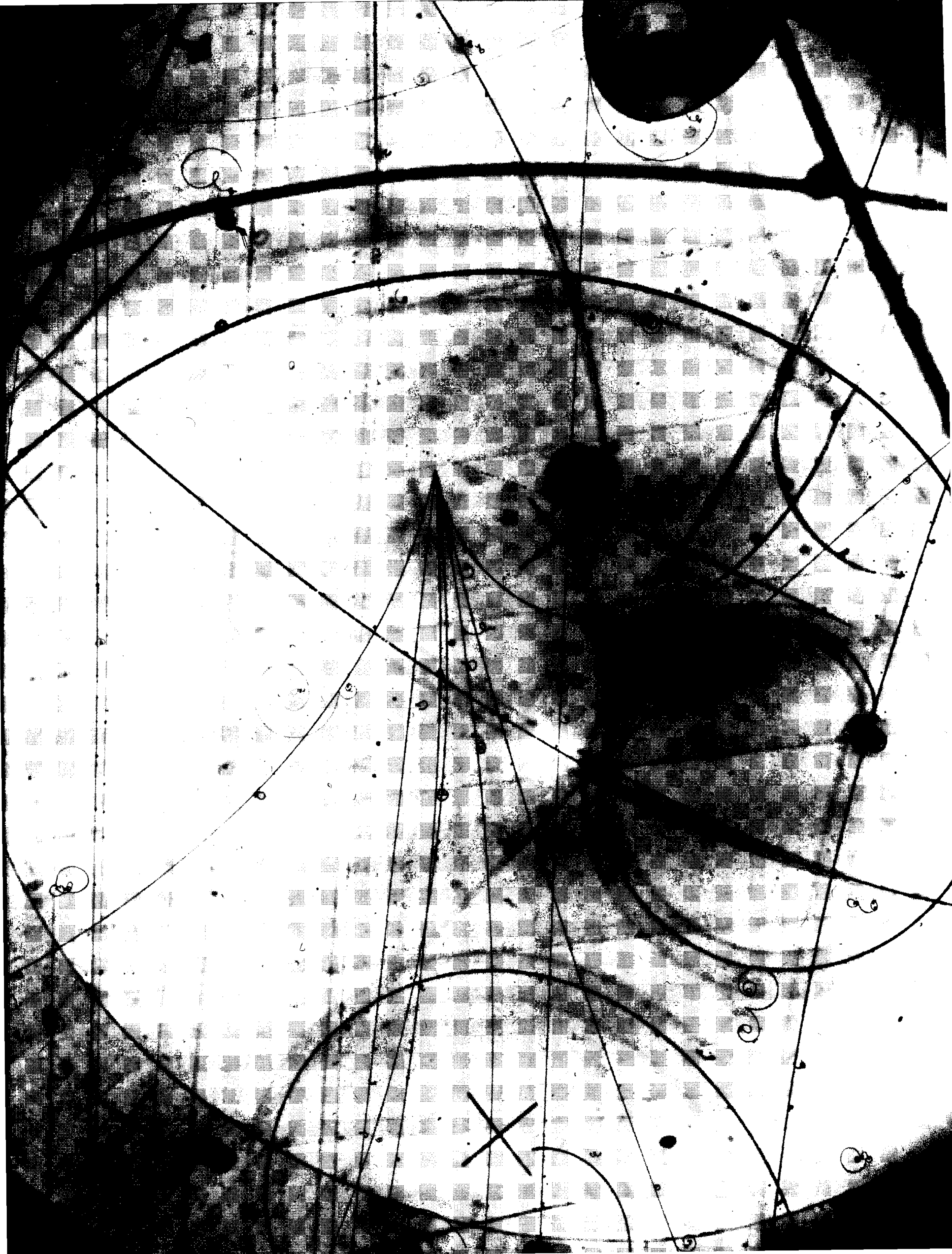
What follows below is the edited transcription of the presentations that were given at the 15 Foot Fest, along with articles that were solicited from individuals who played a major role in conceiving, designing, fabricating, constructing, and operating the 15 Foot Bubble Chamber as well as analyzing the data which it produced.





1970 Summer Study Volume 2





The 15 Foot Fest April 8, 1988

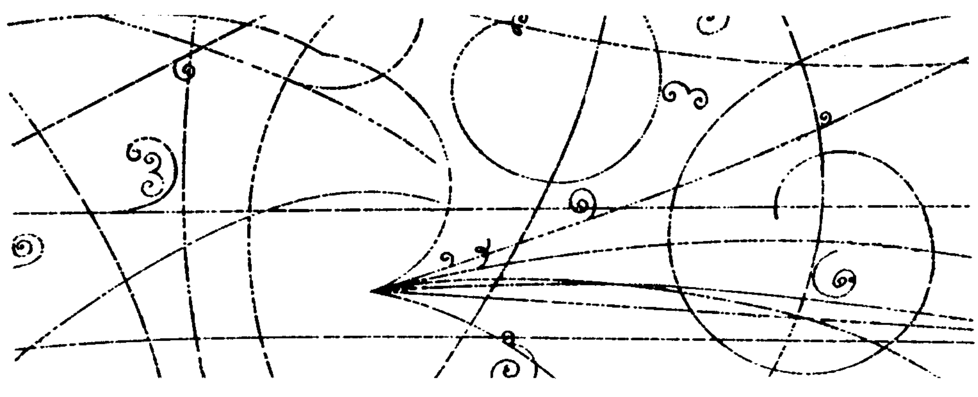
A *fest* is an occasion at which a community of individuals gathers to celebrate. Sometimes in the academic world celebrations are preserved by publishing the proceedings in the form of *festschrifts* from the German words *fest* (meaning festival or celebration) and *schrift* (which means writing). Webster says a *festschrift* is "A volume of writings by different authors [students, colleagues and admirers] presented as a tribute or memorial." What follows below is just such a tribute in which many of those who were intimately involved with the design, fabrication, construction, operation, experimentation, and now decommissioning of the 15 Foot Bubble Chamber at Fermilab recall its history and pay tribute to this productive detector. The presentations appear here in the order in which they were given.

In the introduction, we saw that one of the most original aspects of Alvarez's contribution both to bubble chambers and the history of particle physics was the assembling of a *team* of individuals (some physicists, many not) to be involved with the full scope of the chamber's activities. This type of collaboration has served as a proto-typic model which guided the formation of the sociological structure needed to do many subsequent large experiments. It is this type of team concept, a "community" of individuals with a common goal or purpose, which we see when analyzing the history of the 15 Foot Bubble Chamber. In many ways, the *chamber itself*, i.e., the physics it made possible, was the focal point around which this diverse group of technicians, operators, physicists, and engineers came together. In an even more profound way, it was the *chamber* that often determined the order and social life of the families of those who were involved with it. Whether it was the long hours invested in the scanning rooms by graduate students and professors, the seemingly endless stream of midnight shifts that operators worked to keep the chamber running, or the phone call at 3:00 a.m. which necessitated a trip to the laboratory to fix a component or troubleshoot some other type of problem that was inhibiting or stopping the chamber from taking data, the 15 Foot exerted a powerful influence on the lives of the people that were involved with it. As some of the users recalled in their remarks, this was one of the most endearing aspects of working with the 15 Foot.

The presentations below reflect this "community" commitment to the chamber. In what follows, the full technical and sociological scope of that commitment, as well as the history of the 15 Foot, is encapsulated. We gain glimpses of the technical side in Charles Baltay's descriptions of the unique contributions that the 15 Foot Bubble Chamber made to high-energy physics. The social identity of the community of people who ran the chamber is revealed as Jim Ellermeier creates images of the battle scars received during (and after) Bubble Chamber Team softball games.

In a day when many historians, sociologists, and philosophers of science are attempting to "de-throne" the epistemological authority of science by interpreting science through the subjective hermeneutical grids of their own disciplines, more than ever an appropriate view of the sociological components of modern high-energy physics experiments is necessary. The type of sociology and community dynamics which rise naturally from the presentations below show a necessary and salient aspect of the human side of science without attempting to dismantle the epistemological certainty upon which the overall tenets of modern experimental science is based.

The complexity of the chamber itself and the difficulty in accumulating and interpreting the final physics data that was created in the 15 Foot Bubble Chamber, are testimony to the fact that this last generation of modern experiments is a difficult thing to describe systematically. This is especially true if we attempt to describe them in terms of what appears to be an integrated interweaving of their sociological, experimental, theoretical, and mechanical aspects. The stories which follow shed light on this "scientific" culture and are a small sample of the raw material out of which more complete historical reconstructions must come.



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A TANK LEVEL	4.6	PRESSURE	62.38
C TANK LEVEL	—	PRESSURE	45.04
D TANK LEVEL	0	PRESSURE	76.12
U TANK LEVEL	42	PRESSURE	54.66
Z TANK LEVEL	33.5/3	PRESSURE	4.664
MAG LEVEL	1/7	PRESSURE	2.7
HE LOW PRESS.	79.4	NAL 2	
NAL 1		AIRCO	
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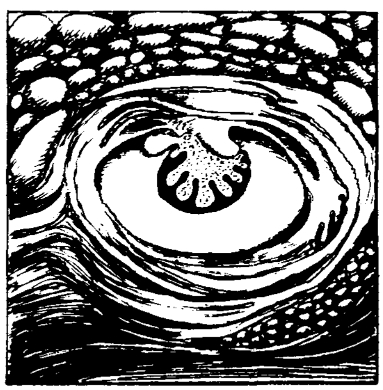
Kenneth Stanfield

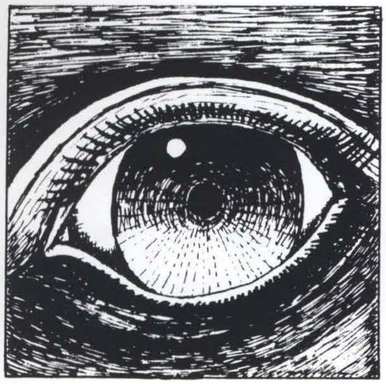
Fermilab

It is my pleasure to welcome you here to an event that marks the end of an era. Rather than giving a formal introduction which encapsulates the long and illustrious history of the 15 Foot, I'll share a personal incident about the bubble chamber business that happened to me about 15 years ago when I was a young assistant professor. I was standing there working (probably with epoxy dripping from my fingers while building some spark chamber) when a dapper young physicist walked up to me and asked, "What's the difference between a bubble chamber physicist and a counter physicist?" I had to frankly admit that I didn't know. Without hesitation he replied, "The counter physicist leaves knuckle tracks in the snow." As I look around, it seems that some of the arms of the physicists sitting in front of me are getting longer by the day.

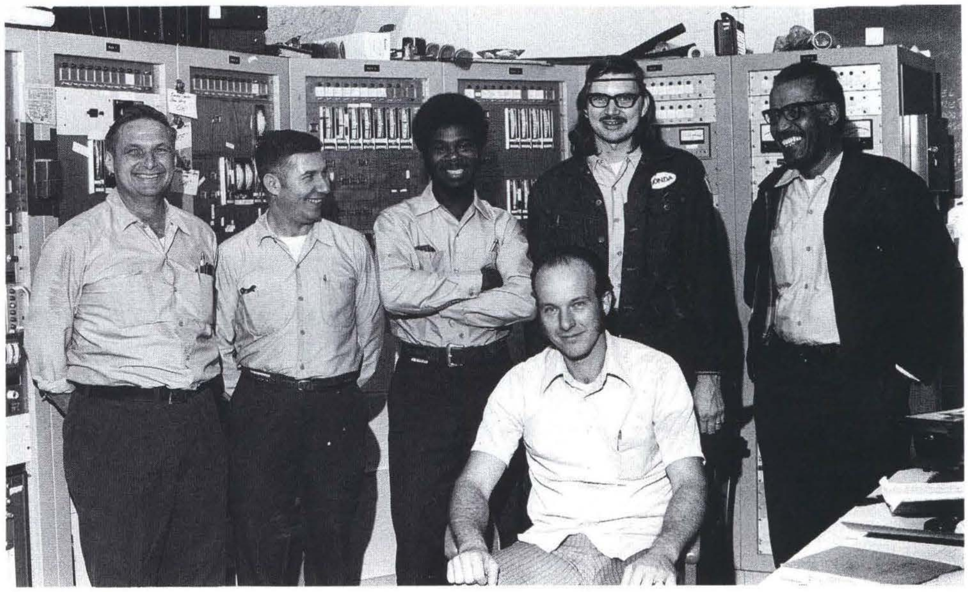
On a more serious note, I'd like to thank the organizers of the 15 Foot Fest. The list is much too long to repeat in full, but some of the names that stand out in my mind are John Norris, Thornton Murphy, Bert Forester, Stan Stoy, and John Urbin. Thank you all for organizing this affair. In addition, I want to personally give a special note of thanks to the crew and the leadership of the 15 Foot Bubble Chamber. In 1982, when I first became organizationally responsible for the Bubble Chamber, the three experimental areas were reorganized into a single department. What I inherited at the Bubble Chamber was a strongly motivated, dedicated, and very capable crew of people who, in addition to being talented individuals, had a strong tradition of formative leadership from people like Bill Fowler, Russ Huson, George Mulholland, Jim Kilmer, Gert Harigel and Wes Smart. So thank you all for making this chamber a success over those long years.

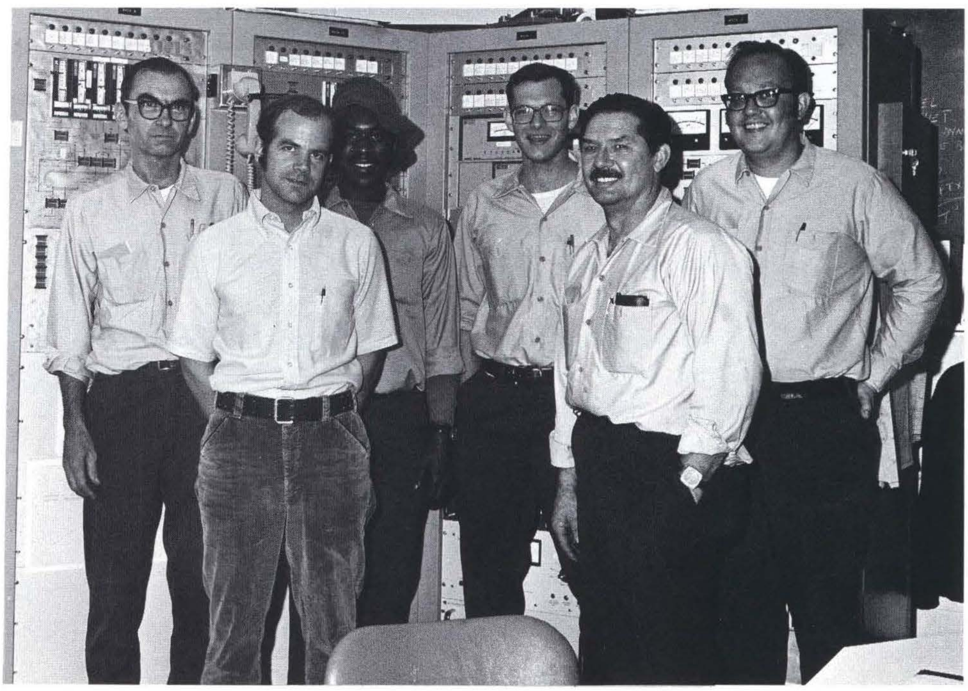
I thought I would give you some bubble chamber statistics to set the operational record of this machine into its larger historical framework. The bubble chamber crew was formed in about 1968 with the first operation of the chamber on July 9, 1973. Since then it has taken almost three million pictures. About ten percent of this number was during this last very successful run. So once again, welcome. I hope you enjoy reminiscing about the role you played in the history of the 15 Foot Bubble Chamber as you listen to the remarks that will be made during the course of the presentations. But before our 15

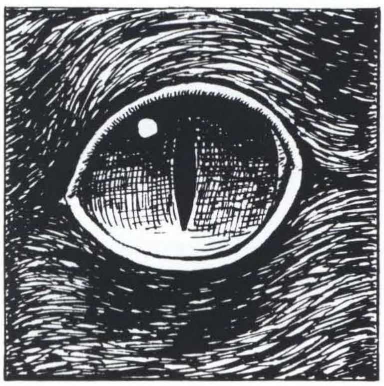


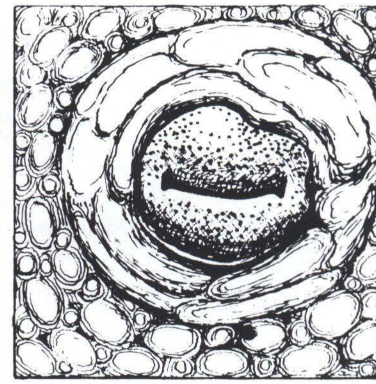


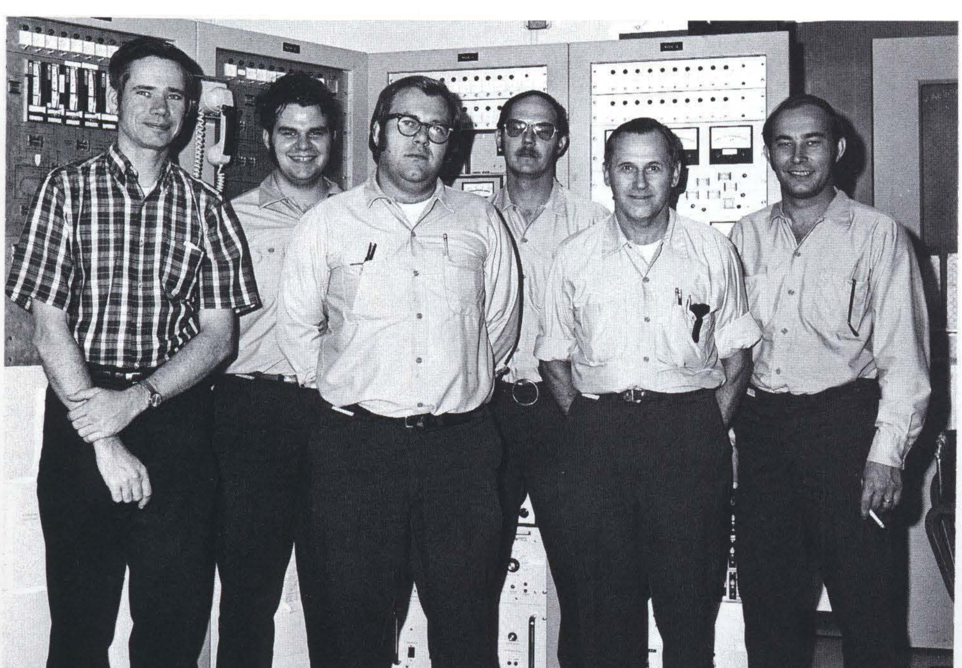
Foot Fest Chairman comes to speak to us, let me say most of all, enjoy the party!

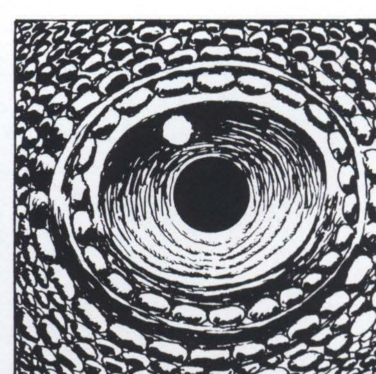


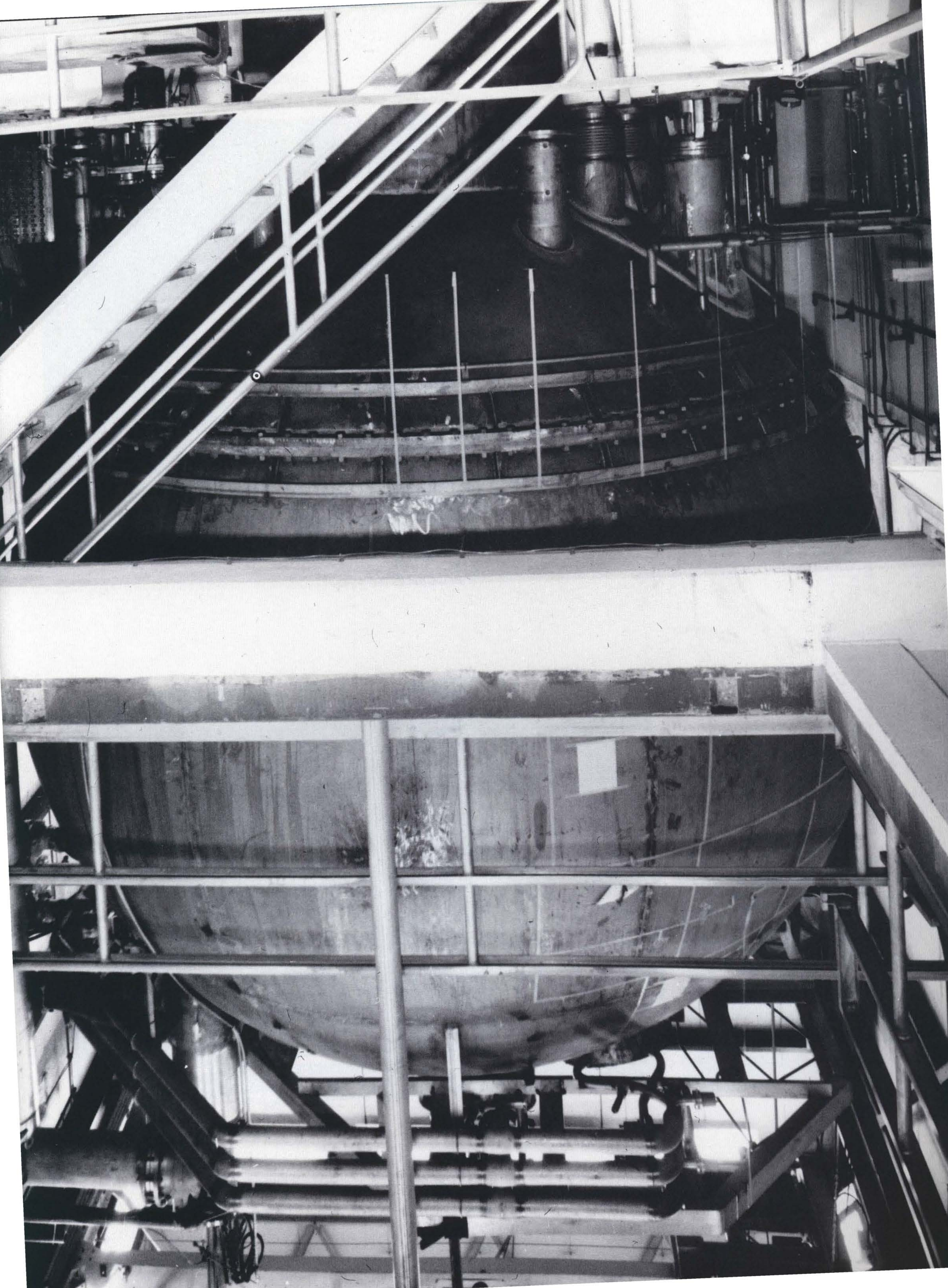












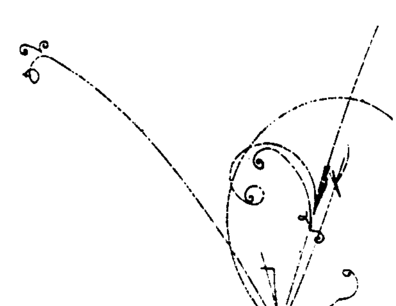
C. Thornton Murphy

Fermilab

It has been my dubious honor, as the Head of the Cryogenics Department in the Research Division, to preside over the closing of the 15 Foot Bubble Chamber. So I thought the least I could do was to have a really good party for the crews which have so ably built and operated the chamber over the past 15 years. We have tried to invite to the Fest everybody who ever had anything to do with the chamber.

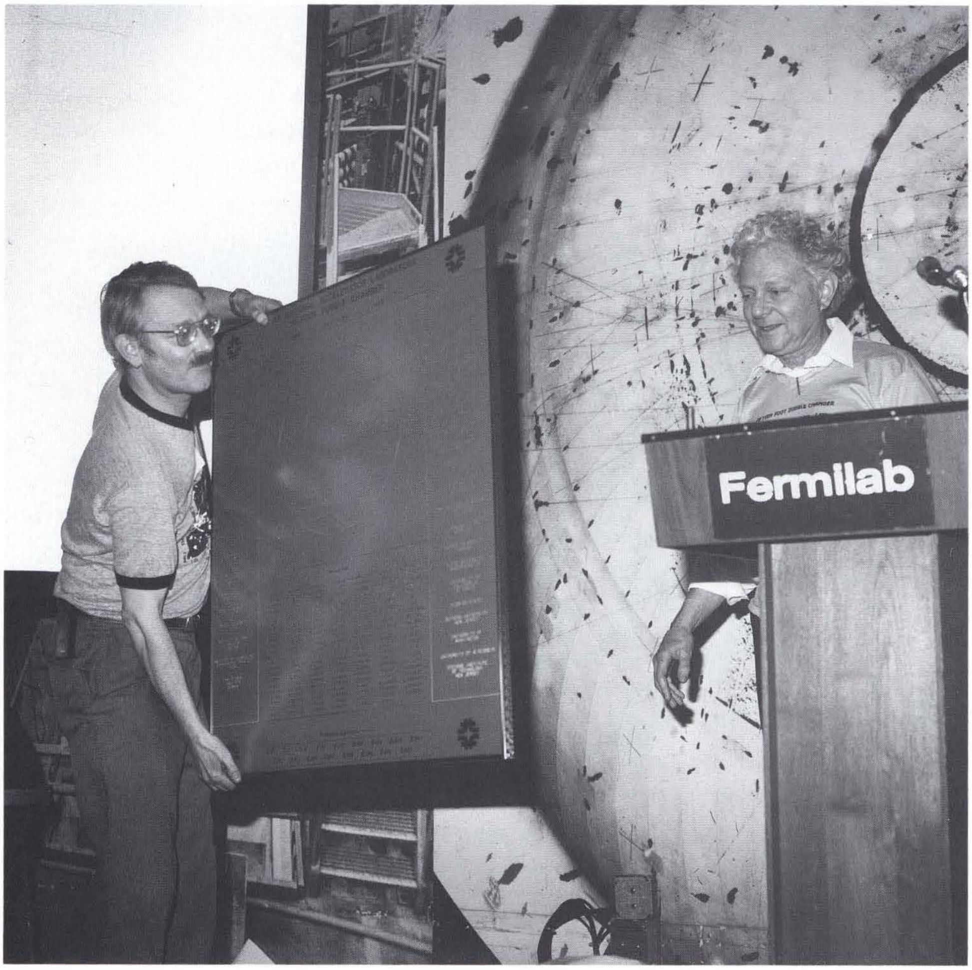
The 15 Foot Bubble Chamber Group has always been a group in a much larger department: first the Neutrino Department, then the Experimental Areas Department, and finally the Cryogenics Department. I think I am the 15th Department Head to have the chamber to worry about. It's not clear that any of us have done anything more useful than just worry, for the group has always been a very self-sufficient and independent outfit. It has had only six group leaders in the same time period: Bill Fowler, Russ Huson, George Mulholland, Gert Harigel, Jim Kilmer, and Wes Smart - a much more stable group than its parent organization! They never needed much outside help; they fixed everything themselves, including sometimes even the building. This self-sufficiency has been their great strength: they knew that if something didn't work, there would be no one else to blame.

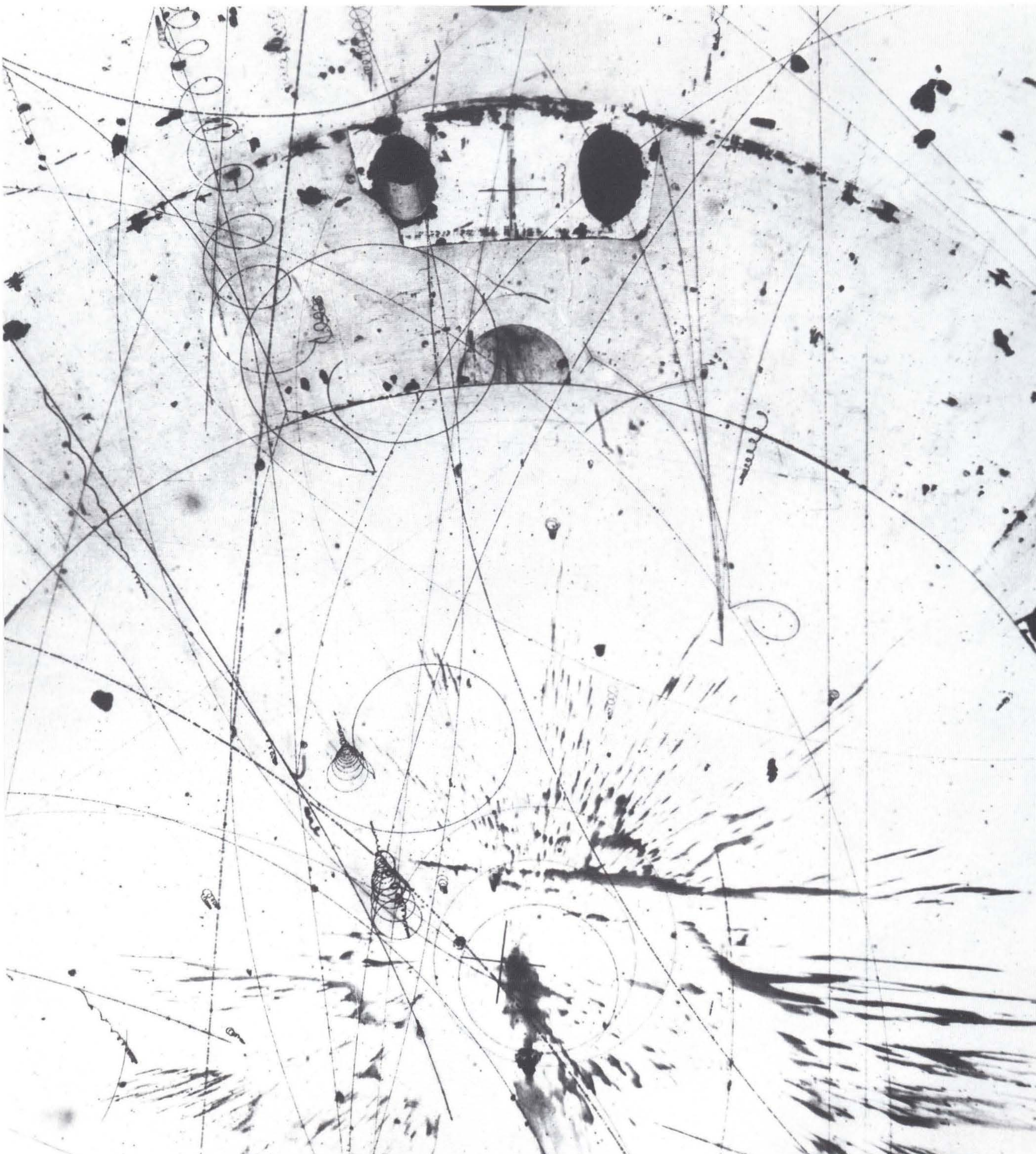
I'd like to illustrate this independence with a story from my own experience. A number of years ago, when I was doing an experiment with the 15 Foot, I went into the control room to ask the crew to change the flash inhibit signal which was coming from beamline counters. "Oh no, we can't change that, it belongs to the Neutrino Department," a crew member replied. "But you *are* the Neutrino Department," I asserted. "No, we're the Bubble Chamber Department." The next day I related this episode to the Head of the Neutrino Department, a friend whom I hoped I could rile a bit. Department heads often have swelled heads about their authority. But he was cool. It seems that the last time he had visited the chamber control room he was asked who he was and was requested to remain on the north side of the work table.

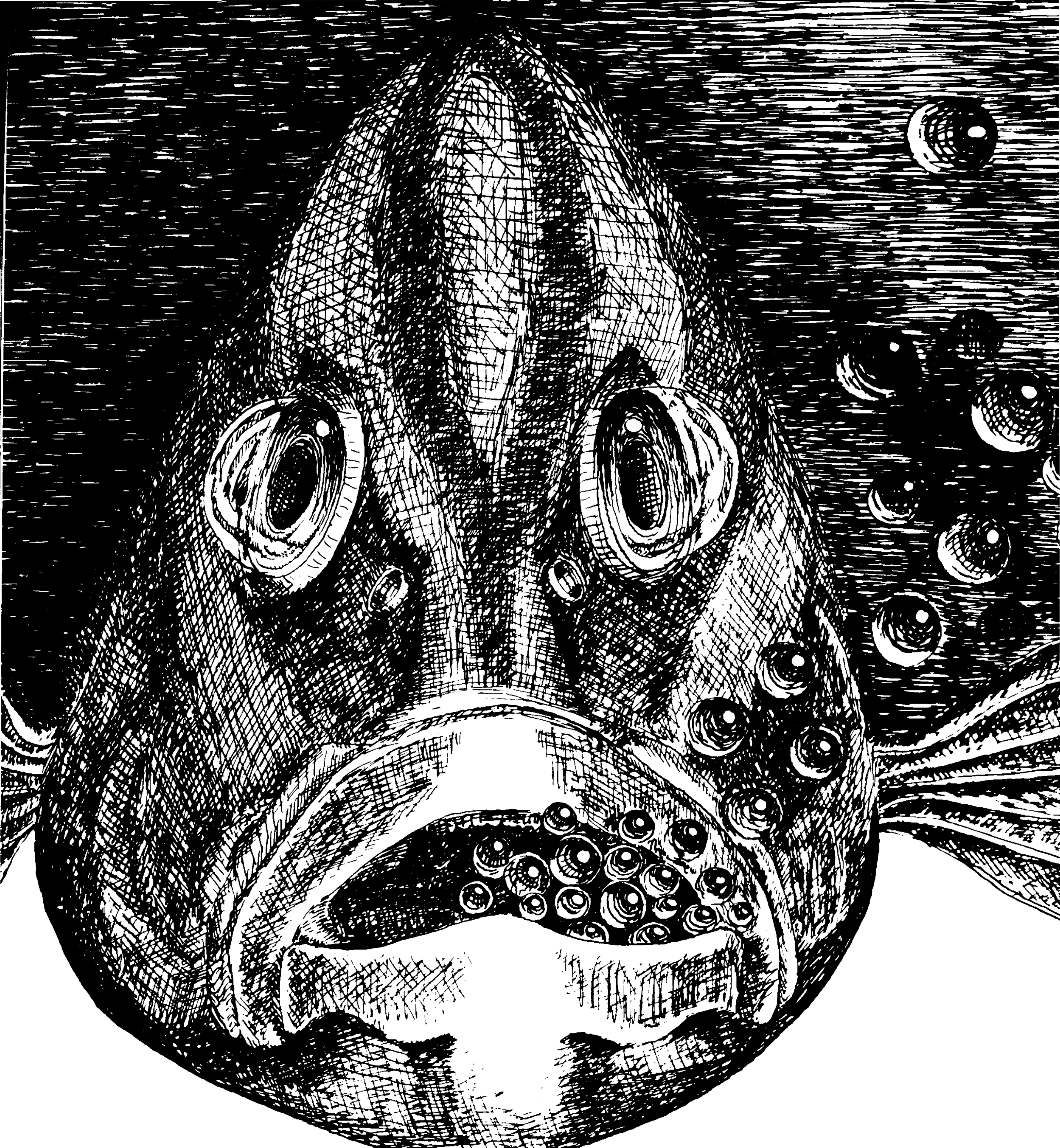


Before the party I have arranged to have a few members of the 15 Foot community provide some verbal testimony of its excellence - and a few more anecdotes, I hope. We have representatives from the builders, the experimenters, and the operators, with no attempt at completeness nor equal time. I will read a few of the congratulatory telexes after the coffee break, and the ceremonies will close with a presentation by our Director, Leon Lederman, of a commemorative plaque to the many workers whom we are honoring today.

The conception, construction, and operation of the 15 Foot Bubble Chamber has been one of those team efforts for which the credit is very widespread. However, there is one person whose efforts in all of these phases stand out especially: Bill Fowler. He is clearly the "father" of this important scientific tool - and now the grandfather, in his present role as chairman of the safety review panel. So at the conclusion of the presentations today, I will ask him to say a few words in accepting the plaque on behalf of the rest of you. We must get him to write a correct history sometime, to complement today's anecdotal record.







Design Report

October, 1969

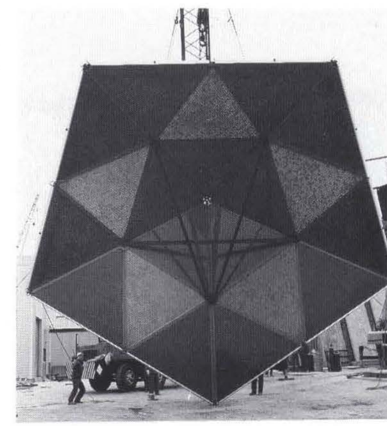
25-Foot Bubble Chamber

National Accelerator Laboratory

Brookhaven National Laboratory

Fred Russ Huson

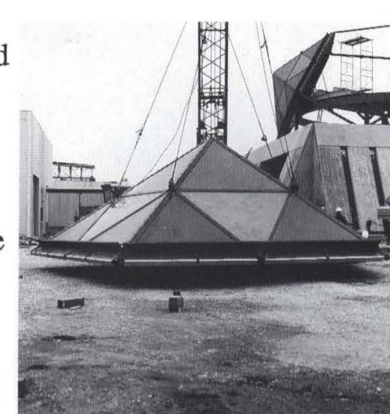
Texas Accelerator Center

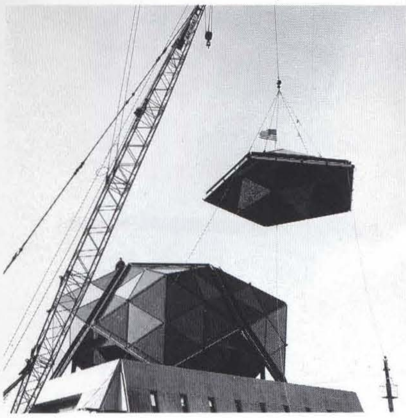


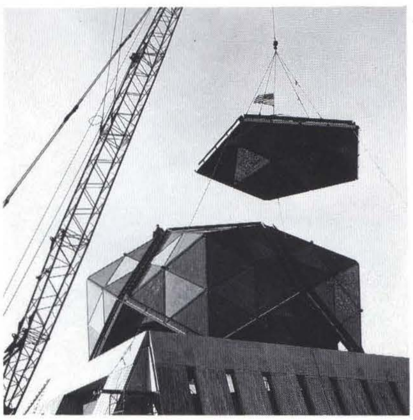
I've jotted down a bunch of incidents or accidents (or whatever you want to call them) that have happened in regard to the 15 Foot. I'm sure that I didn't remember some of the more important ones, and I probably won't remember to mention all of the most important people either, so I apologize ahead of time.

Bill Fowler started with Fermilab early in 1970 or late 1969, I'm not sure. In July of 1970, I joined the Laboratory. We were still less than a thousand in number then, 946, and one of the things I wanted was to hire an experienced bubble chamber engineer to operate the chamber. So George Mulholland came with me and joined the group at that time. When the three of us began building this chamber, the site where the 15 Foot was to stand (and a large part of the overall Fermilab site up to the Main Ring) was literally a cornfield. Construction of the high rise had not even begun. The three of us had some questions about how well all of this would work out. We had a conference in which Malcolm Derrick was one of the spokesmen and when he heard us talking about building this chamber and running it with a neon hydrogen mixture, he commented that we belonged in *Alice in Wonderland* if we thought we'd ever make it work with that type of mixture. He claimed that they would never mix and work properly. I think we proved him wrong.

I wanted to be sure and mention some of the important people who participated in building the chamber. We put together a collaboration of U.S. scientists to build this thing, and the history of the chamber shows that it certainly was a very successful collaboration. Bob Watt from SLAC built the expansion system. John Purcell (then at Argonne) and I worked closely in building the bubble chamber magnet. Another member of the collaboration was Bob Louttit from Brookhaven National Laboratory, who helped us a great deal with the optics. Paul Hernandez served as our safety monitor through the entire project. Milt Vegans from Batelle Memorial Institute was one of the expert engineers who did a lot of the detail calculations and Andy Mravca certainly helped us get things through what was then called the Atomic Energy Commission. So again, I'm sure I'm leaving out some names that I should mention, but those that I did mention were an important



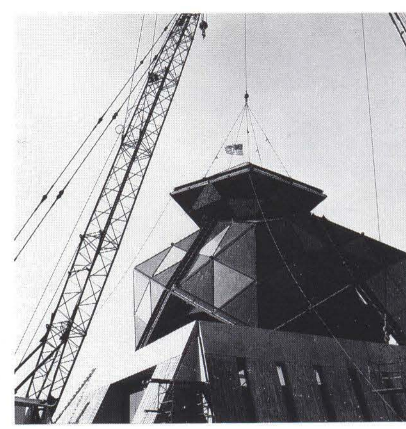


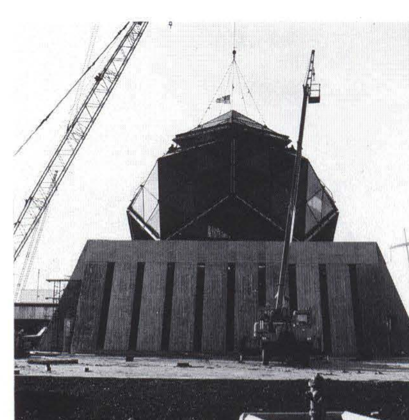


component of the people across the country who participated in building this chamber. I recall a couple of years in which I flew at least once a week to either SLAC to see Bob Watt, or to Brookhaven to meet with that part of the collaboration. I also spent a lot of time down in Virginia at Brunswick. The collaboration worked extremely well together.

Bob Wilson liked us to construct models of various systems, so we built a lot of models in those days. One of the first things we did was to have Jose Pores build a full-scale model of the whole bottom part of the chamber. He built it over in the Village. The full-scale model helped us tremendously in regard to visualizing how to lay pipes out around corners and so on. I recall when we were talking about designing the building that would eventually house the Bubble Chamber, we came up with the idea that it should look like a geodesic dome, with the crane mounted up inside of the dome. A lot of people thought we were crazy, but I built a model out of plastic anyway and I took it into Wilson's office to show it to him. He took it and bounced it around a little, then turned around and threw it at me as hard as he could. It didn't break apart, luckily, and he said "Great! Build it." That's how we got started on the building. At that time it was more of a classic geodesic dome, but Angela Gonzales modified it to more of a pentagon shape, using equilateral triangles to make up the pentagons. Around that time, I think Bob Sheldon from the Accelerator Division was working on the epoxy for the Main Ring magnets and he came up with the idea of making all the panels of the dome out of beer cans and fiberglass. We decided to advertise in the Batavia-St. Charles area for people to contribute pop and beer cans to the project. The only problem with that great idea was that we accumulated enough cans to build an entire laboratory complex.

In regard to the process of building and subsequently operating the chamber, it is (in some sense) good to have it shut down because we don't have to worry about something coming loose and spilling hydrogen from the chamber. So from that perspective, it's a relief to have it shut down. Over the years, there were no serious accidents with the chamber, but there were some accidents. I recall once when we were testing the expansion system and one of the lines that had about 3,000 psi in it came loose, swung around, and hit Bill Noe, Sr., in the leg. It didn't break his leg, but he certainly limped for some time afterwards. It was a lesson that we learned about tieing





all those high-pressure lines down securely. Just before we moved that same expansion system to Fermilab, I was out at SLAC and Bob Watt and his people were testing components in the nice warm California weather when one of those 3,000-pound lines broke and began to shoot oil all over. The oil went straight up and over the building. In all the confusion we didn't worry too much about where the oil was going until somebody came screaming from around the corner. The oil had gone up, over the building, and came down into the back seat of a convertible that was parked in the parking lot. It filled it up with oil! We got in trouble for that.

Another incident worth mentioning is the time that the bubble chamber magnet quenched. I really don't think the quench was caused by any type of technical problem. I think George Mulholland was really just testing the design of our quench protection system to make sure that it really worked. Anyway, for all those years, given the amount of hydrogen used and so on, the 15 Foot Bubble Chamber really did get by with very few problems and I think that is a positive statement about the quality of work, operation, and people that were part of the on-going involvement with the machine.

Another incident I remember happened with Bob Wilson when we were building the nose of the chamber, the so-called "Charlie Brown" nose. At one time we were having a difficult time fitting the nose into the magnet, making a true 15-foot bubble chamber out of it. Bill Fowler and I went to Wilson to talk to him about making it a 14-ft. 6-in. chamber. I think Bill probably remembers the comments as well as I do. We still can't repeat them in mixed company, but we built a 15-ft., not a 14-ft. 6-in. bubble chamber.

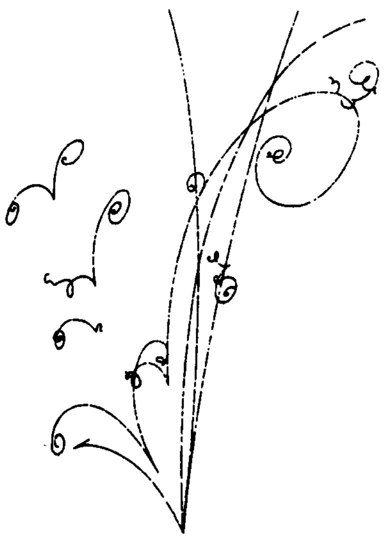
I also recalled when we poured the concrete base for the expansion system. It was 20 ft. in diameter and 60 ft. down to the bedrock and I believe there were at least 30 concrete trucks lined up at one time pouring concrete down into that hole. That was rather impressive.

Then came the day when we moved the magnet into position. At first we were concerned about that 150-ton load as Belding riggers picked it up and began to move it around, bringing it into the building, then setting it down. But that's all there was to it. After it was done, it didn't seem to be that much of a problem.

Some of the tests we had were very interesting. I recall when Hans Kautzky and I were testing the 22-ft. vacuum chamber. I forget where we stopped, but I think it was somewhere around 70-80 pounds. I think we were supposed to go to 100 pounds, but at the 70-80 pound level, the big 2-ft. 6-in. flange was starting to move. That's what was supposed to happen, but it still got a little scary, because if the chamber had come loose, it would have been launched into orbit.

I also recall the first night John Purcell and I were charging up the magnet. As we started to charge it up, the magnetic field was so strong that the building started coming in, being drawn toward the magnet. We had to stop the test and stiffen the steel frames on the building before we could proceed. When we tried the test again, it was very quiet in the building and at about half way up a file cabinet came loose and was pulled over toward the magnetic field, being slammed up against the wall. That kind of left us all perspiring - wondering what was going on. After this, we had quite a few discussions about whether we should go all the way up to 3 tesla or stop at some lower value. We were afraid if we stopped without going all the way we would never reach our goal. We went on to 3 tesla and it worked beautifully! It has worked beautifully ever since. That was a great magnet.

I was just comparing notes with Gert Harigel about how the 15 Foot compared to the BEBC at CERN in regard to the length of time it took to build and operate the chamber for the first time. We started the 15 Foot after the 7-ft. bubble chamber at Brookhaven and the CERN BEBC chamber were begun. Yet we finished before the 7-ft. and I guess Gert has finally convinced me that we didn't quite beat BEBC to the first picture. We didn't beat them, but we did build the chamber very quickly. The first cooldown was about three years to the day after we started construction.

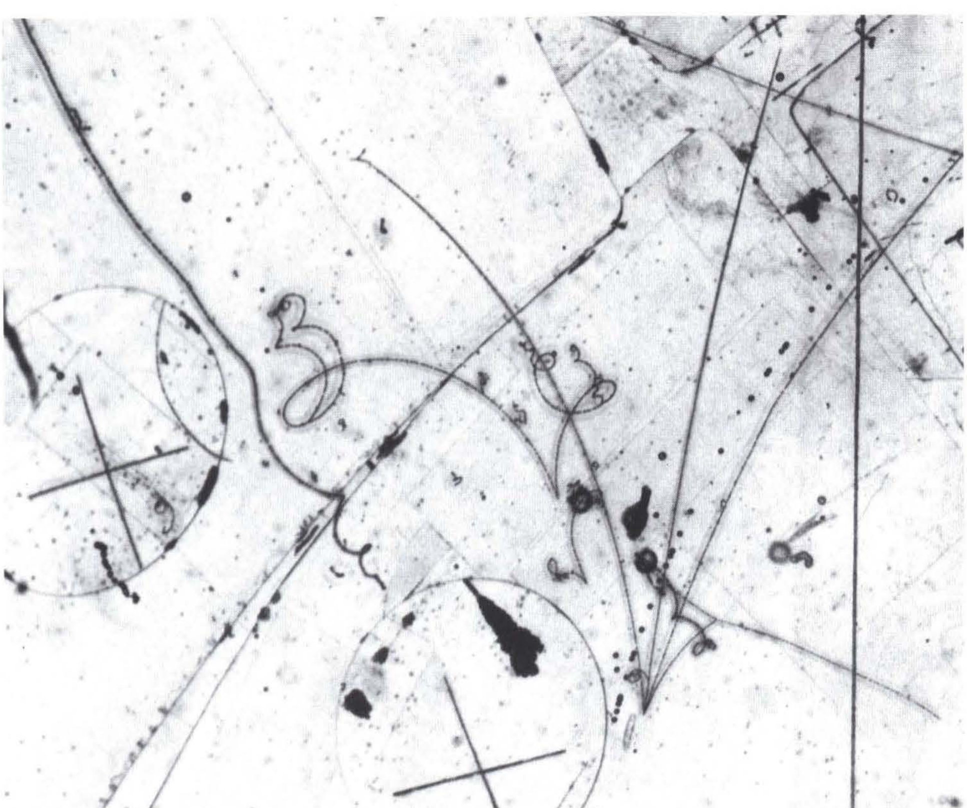


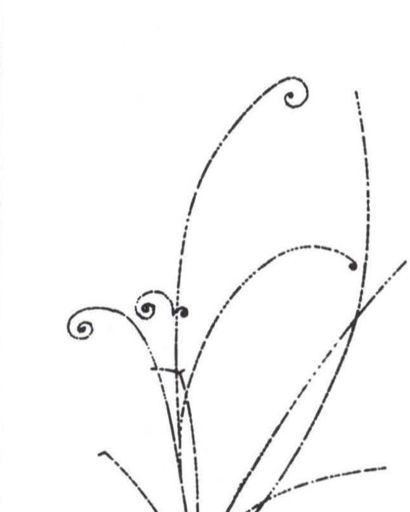
Another short incident that I have written down concerns Gene Beck. I recall one time we had a Bubble Chamber party out at the old brick building. Bill Fowler and I got a call the next day in regard to somebody seen streaking out there in front of the janitors. I don't know who it was.

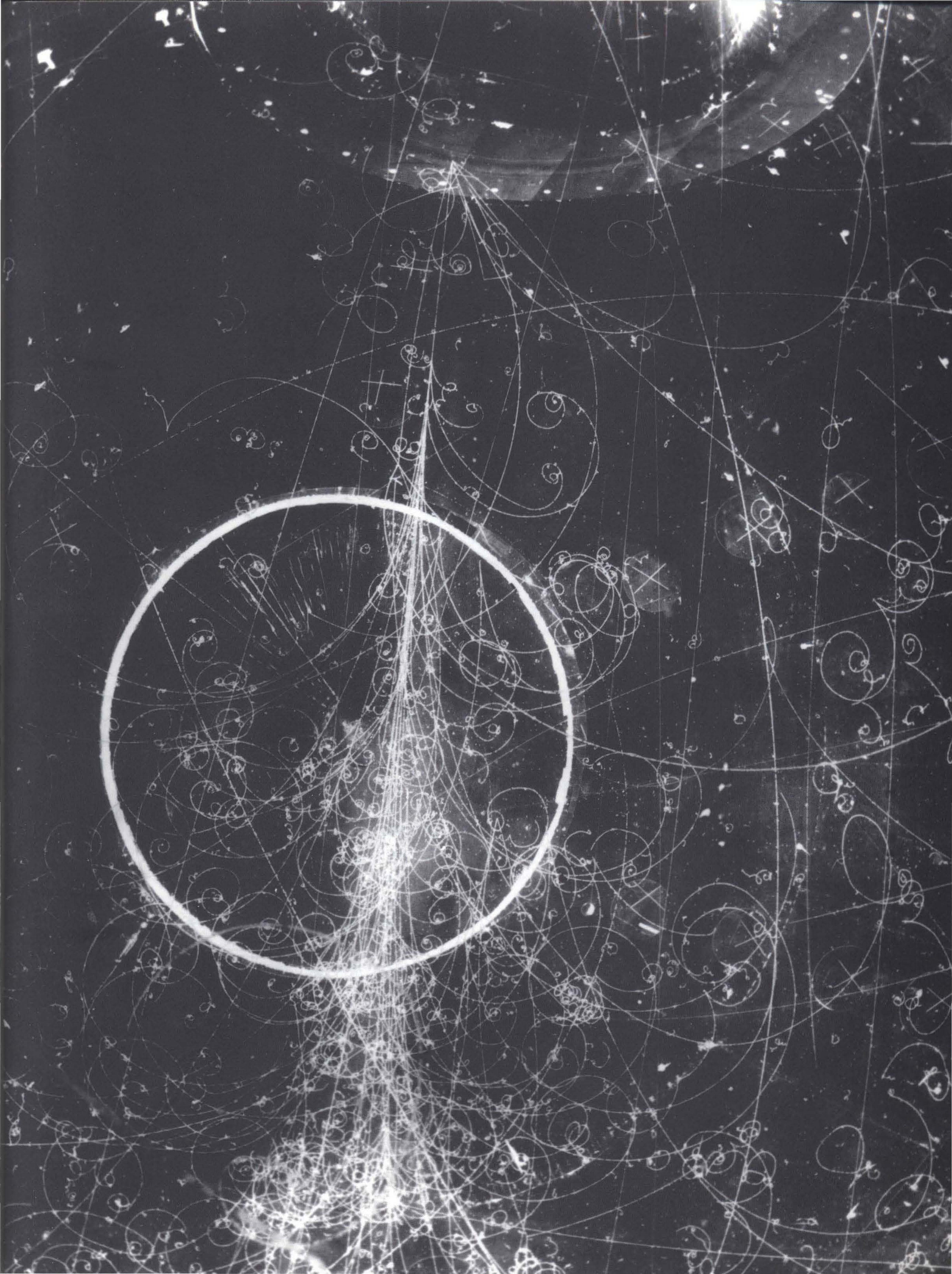
We have a new physics proposal in right now, it's only in a letter of intent so it's not approved, it's not even an official proposal yet, but what we're considering is using the 15 Foot Bubble Chamber magnet for an experiment to detect axions. The idea is that axions coming from the sun would interact with the magnetic field and produce another photon and the detector would have to detect that photon. It's quite a difficult experiment, but it is also an important experiment that would keep the bubble chamber magnet in use.

Another thing I would like to mention in regard to the current use of bubble chambers in HEP, is that I'm on an experiment right now with some colleagues from Columbia University, the University of Massachusetts, Mexico, Fermilab, and ourselves. In some sense our detector is an electronic bubble chamber because we get tracks out of it just like the tracks in our bubble chamber film. There is one slight difference. The 15 Foot Bubble Chamber ran at about 1 hertz, and our new experiment allows us to take data and analyze it at 10^5 hertz (events per second.) So, things have progressed a great deal in the last 15 years.

In closing, I want to once again thank Thornton Murphy for putting this affair together and reiterate how very successful this project has been from beginning to end with no real problems or catastrophes along the way. That's hard to do when building devices and systems of the scale and complexity of the 15 Foot Bubble Chamber.







John Purcell

Texas Accelerator Center

Actually, I had a 25-page speech written up, but I left the papers out in the car, so I'll just make do.

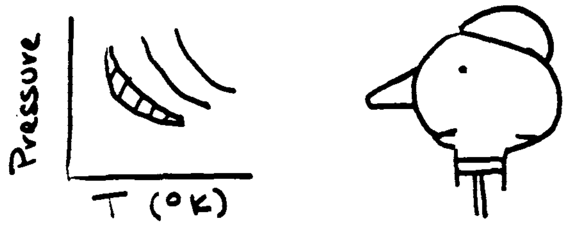
The main thing that struck me when we were building the chamber magnet was what a bunch of young bucks we were and today I look out and see a bunch of old gray haired people around here. So apparently, it's been quite a while.

In regard to the quench that Russ Huson mentioned previously, the magnet behaved exactly as it was supposed to but we never expected that test to actually be made. That was one we could have all lived without. I had been in California for a number of years when that happened and they called me back here in the aftermath of the quench. We had to go over things again very carefully.

The main thing I want to say is that in the years I have spent building magnets, it has been such a pleasure to get to relive some of the high points, and of course, the 15 Foot Bubble Chamber was a real high point in my life. I really appreciate the chance to relive these memories.

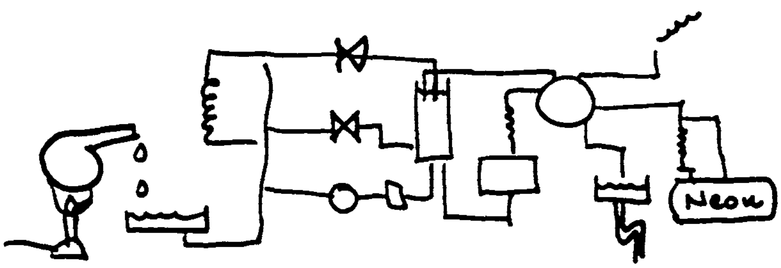
WHAT IS THE 15' CHAMBER?

1. TO THE PHYSICISTS WHO BUILT IT



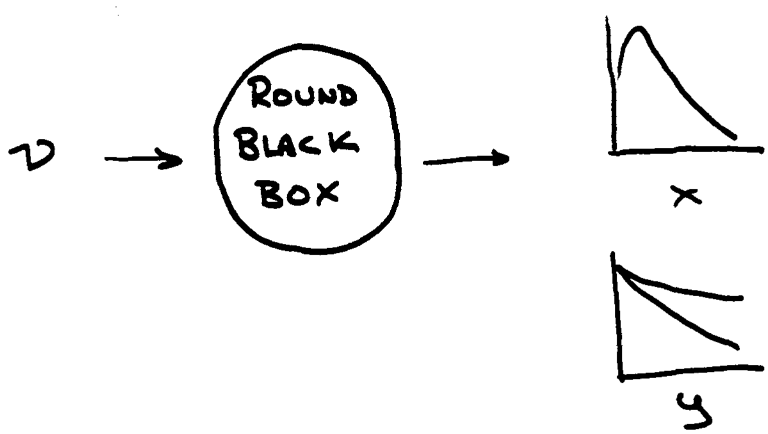
Years of Hard Work

2. TO THE CRYOGENICS GROUP



Years of Hard Work

3. TO THE EXPERIMENTERS



Wait for Phone call that chamber is ready for tracks

4. TO LEON

A sink of valuable beam time that could have been better used to do <u>REAL</u> experiments!

Wait for call that chamber is broken

Charles Baltay
Yale University

I'd like to thank Thornton for having organized this occasion. I think it's a very nice thing to do. It's getting so that I write all my talks on the airplane, and I've gotten used to flying from New York to San Fransisco, which is a nice long flight. The flight from New York seemed very short, so this is a very short talk.

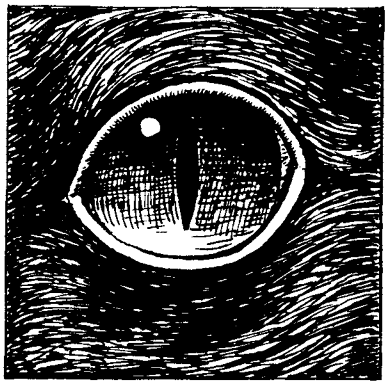
Actually, when I got here I went up to see Leon and asked, "Can you tell me a few good jokes?" but he wouldn't tell me any. He told me that he needs all the jokes he can get himself. So, in thinking about what to say, I was reminded of a cartoon. I'm sure many of you have seen this. It asks the questions "What does an accelerator mean to the builder and the user"? So I tried to apply this to the 15 Foot Bubble Chamber.

1) To the physicists who built it, it represented years and years of hard work.
2) To the Cryogenics Group who helped support it, it also represented years and years of hard work.
3) To the experimenters that used it to do physics, it was like a big, round, black box. They would wait for a phone call telling them that the chamber was ready to take tracks.
4) To Bob Wilson it was an "object of art."
5) To the guy we all looked to, Leon, it was a sink of valuable beam time that he thought could be better used for "real" experiments. And of course, he would wait by the phone to hear that the chamber was broken so the Laboratory could get on with the physics program.

Actually, I'm just kidding. Leon has always been a source of support and inspiration for this program and for that reason, we did actually achieve a very impressive and very major experimental program.

Thornton kindly sent me some of the statistics. There were a total of 17 experiments done with a variety of neutrino and anti-neutrino beams. There were wide-band and narrow-band beams with four different mixtures, and the number of pictures for each experiment that were taken. The big picture hogs were the neon experiments. There were a total of about 3 million pictures taken by some 37 institutions and I'm told that over a hundred papers resulted from these data.

Of course those were easy days for experimenters. To propose an experiment, all you had to do was make yourself a chart of the beam types (wide band, narrow band, neutrino, anti-neutrino) and then look at the mixtures that would fill the chamber (hydrogen, deuterium, or light neon or heavy neon), find an empty box and say "Ah ha, that's a good experiment to do." Then you'd quickly write a proposal and it would usually get approved. The figure below shows that quite a few boxes are still empty, so there is still some room for reconsidering this decommissioning thing.



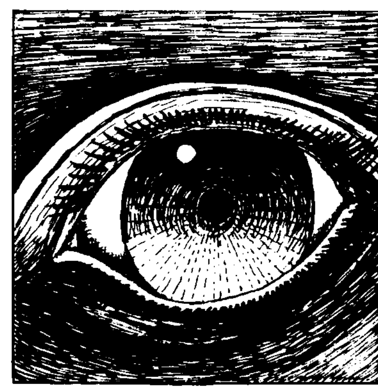
15 Foot Bubble Chamber Experiments

Beam	Particle	Hydrogen	Deuterium	Light Neon	Heavy Neon
Wide Band	ν	45 Nezrick	545 Snow	28 Fry	53 Baltay
	$\bar{\nu}$	31 Derrick	390 Garfinkel	180 Ermslov	172 Lubatti
Narrow Band	ν				380 Baltay
	$\bar{\nu}$				388 Peterson
Quad Triplet	ν			546 Huson	
Tevatron W.B.	ν	632 Morrison Peters			
Hadrons	π^-	234 Huson			
	π^+	341 Ko			
	p	343 Engelman			

Even though there are boxes left, we did cover most of the wide-band beams using various liquids. But in preparing this talk, the thing I have asked myself was, "What has this chamber really done for high-energy physics?" and the answer is that it has made a very unique contribution to neutrino physics. I tried to write down very qualitatively what the unique features of this chamber were. As a general statement, Steinberger wiped out everyone in neutrino physics. He did everything better than everybody else, except for the 15 Foot!

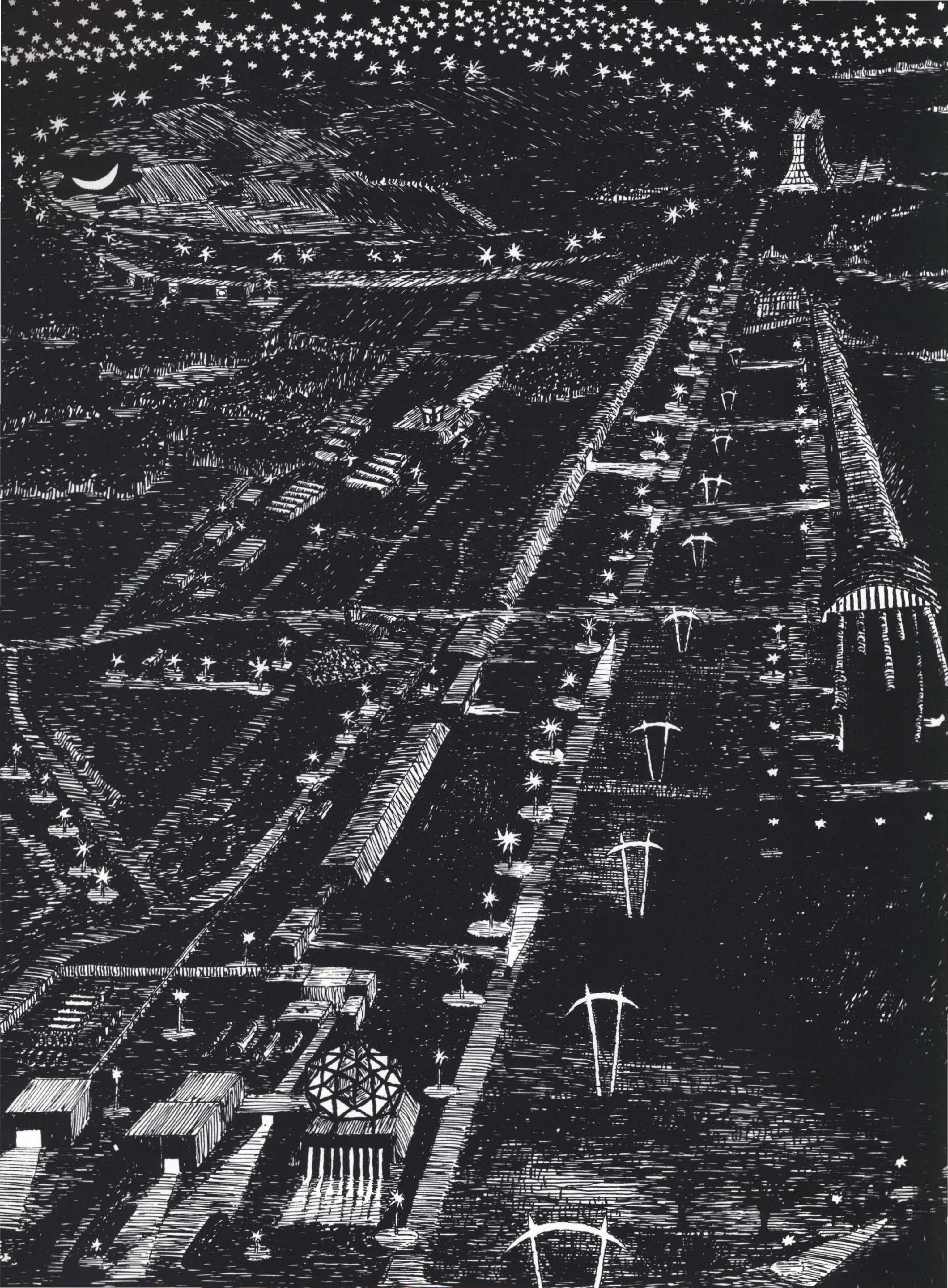
This was because there were some capabilities that the 15 Foot had that none of the other experiments had, namely, seeing electrons, strange particles, K's and Λ's, the ability to see detailed hadrons, and the ability to see details of the vertex, especially in this last run with holography. These were the abilities of this chamber that made it possible to make a unique contribution to neutrino physics. And this is not the whole story. This is a very brief summary in a very brief talk.

We could also mention the areas of charm production by neutrinos starting from the very early days of the chamber and coming all the way to the present experiment (which hopefully will produce some charm events). Also, the chamber produced events of neutral current processes and hadron production by neutrinos which provided tests of QCD. So let me reiterate that this chamber has made a unique contribution to neutrino physics, and I think that that is the important thing which justifies the whole effort.



Let me close with the strongest sentiment that comes to mind. That is to say thank you to the people who have done this. Since my bubble chamber days are over, I am now actually working for a living. I'm building a detector and I keep thinking back to the good old days when I was doing bubble chamber physics, when those guys did all the work. They built the chamber, they made it run, then called us and said, "It's ready" so we could walk in and take the pictures. Those really were good days.

So I want to thank Bill Fowler, Russ Huson, Wes Smart, George Mulholland, Gert Harigel, Jim Kilmer, and all the other people whom I cannot list who made this chamber work. In the name of all the users who have gotten physics from this chamber, thank you. This was a great facility, it was a great period in our lives, and it will never be that easy again.



Gert Harigel

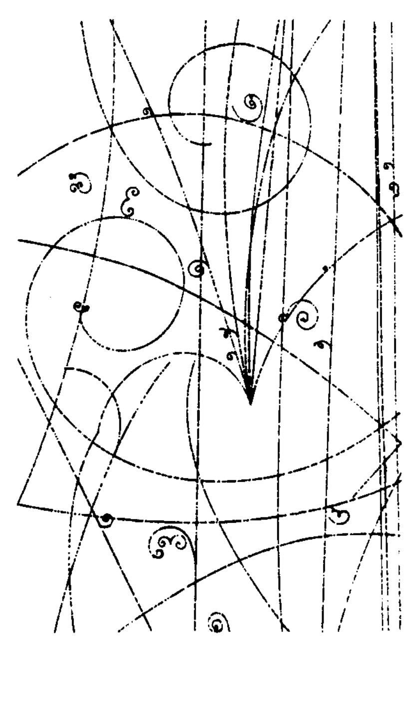
CERN

I'm very happy to have the opportunity to say a few words in the name of CERN's Experimental Physics Division and in the name of the former Big European Bubble Chamber Group. In a way it is sad that you have had, as we did a few years ago, to say goodbye to a highly successful experimental instrument, a very sophisticated, multi-faceted one which demanded all our skills, imagination, foresight, enthusiasm, and endurance to operate. You (and I mean this in the "correct order" of importance), the secretaries, technicians, engineers, and physicists all have reason to be very proud of the success of the chamber and of its contribution to our knowledge about nature.

If the number of publications in scientific journals (estimated at the time of shutdown) can be taken as a measure of the quality of research, then you have done better than CERN if only by a margin of 2 percent. In many technical developments, you were certainly ahead of us by years and you did a lot of pioneering work. During the last runs, in particular with the development of holography, you opened up a vast window with possible applications of this technique far beyond the field of high-energy physics. We on the other side of the Atlantic would like to congratulate you sincerely for all of these achievements. We hope that all who worked on the chamber will find an equally interesting and challenging area to work within the Laboratory, which still has the highest-energy beams in the world.

Concluding my official remarks, it must be mentioned that the first large-scale technical collaboration between Fermilab and CERN was with our two big bubble chambers. I believe it worked very well, and to the great benefit of physics. We certainly want to continue on this track.

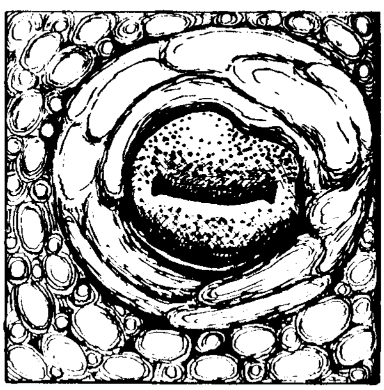
Finally, let me say a few personal words. I don't know which hat I should put on, the one I wore when I helped to run the chamber or when I looked at the physics outcome. When I first came to Fermilab in April 1974, at Russ Huson's and Bill Fowler's invitation, I found a "giant baby" that had been abandoned, more or less, by some of its "fathers". Originally, I think there were almost a dozen "fathers" involved in the business: Bill, Russ, Bob, George, Hans, Wes, John, to name just a few. When I saw the situation, a phrase from a German



painter and humorous poet, Wilhelm Busch, came to my mind. "Vater werden ist nicht schwer, Vater sein dagegensehr." Translated into English it means something like: "Producing a baby is easy and fun, but to babysit is not to everybody's taste."

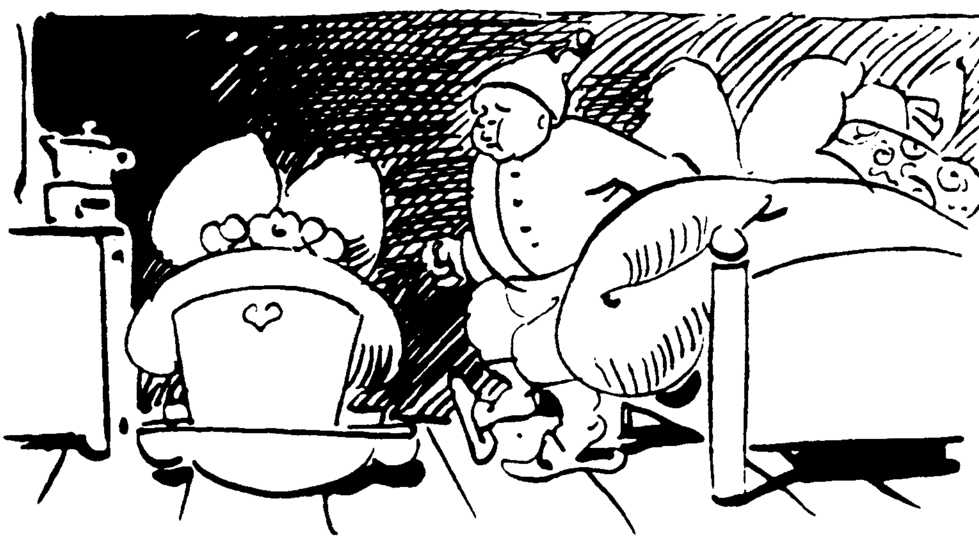
Some of the fathers of the 15 Foot stood by their commitment and they taught their child such things as how not to wet the floor of the pit. As a reward for this good behavior, it was protected with umbrellas against the rain which leaked through the roof. Sometimes its behavior was capricious, not like its counterpart in Geneva, which was predictable to the last second and worked reliably like a Swiss clock. But there was a reason for this distinct behavior; in a word, "You don't get anything for nothing." There were at least three times as many fathers involved in producing the BEBC bubble chamber, it took almost three times as long to get the first pictures, and (expressed in dollars or Swiss Francs) it probably cost three times as much as the Fermilab 15 Foot Bubble Chamber (the magic number "three" to be taken with a grain of salt).

Which of the two bubble chambers was the most rewarding to babysit? Well it's not that "cut and dried." Let's look at BEBC and its positive aspects. It gave the cooks, and we had one in each crew, ample time and opportunity to prepare delicious lunches and dinners while the rest of the crew could sit down and enjoy our French-style meals in a peaceful, quiet atmosphere. This often took half of the shift time. But, not everybody can take or enjoy the good things all the time, at least this was true for me, so I escaped frequently to Fermilab to be a little more challenged, excited, and worried (and to go on a diet).

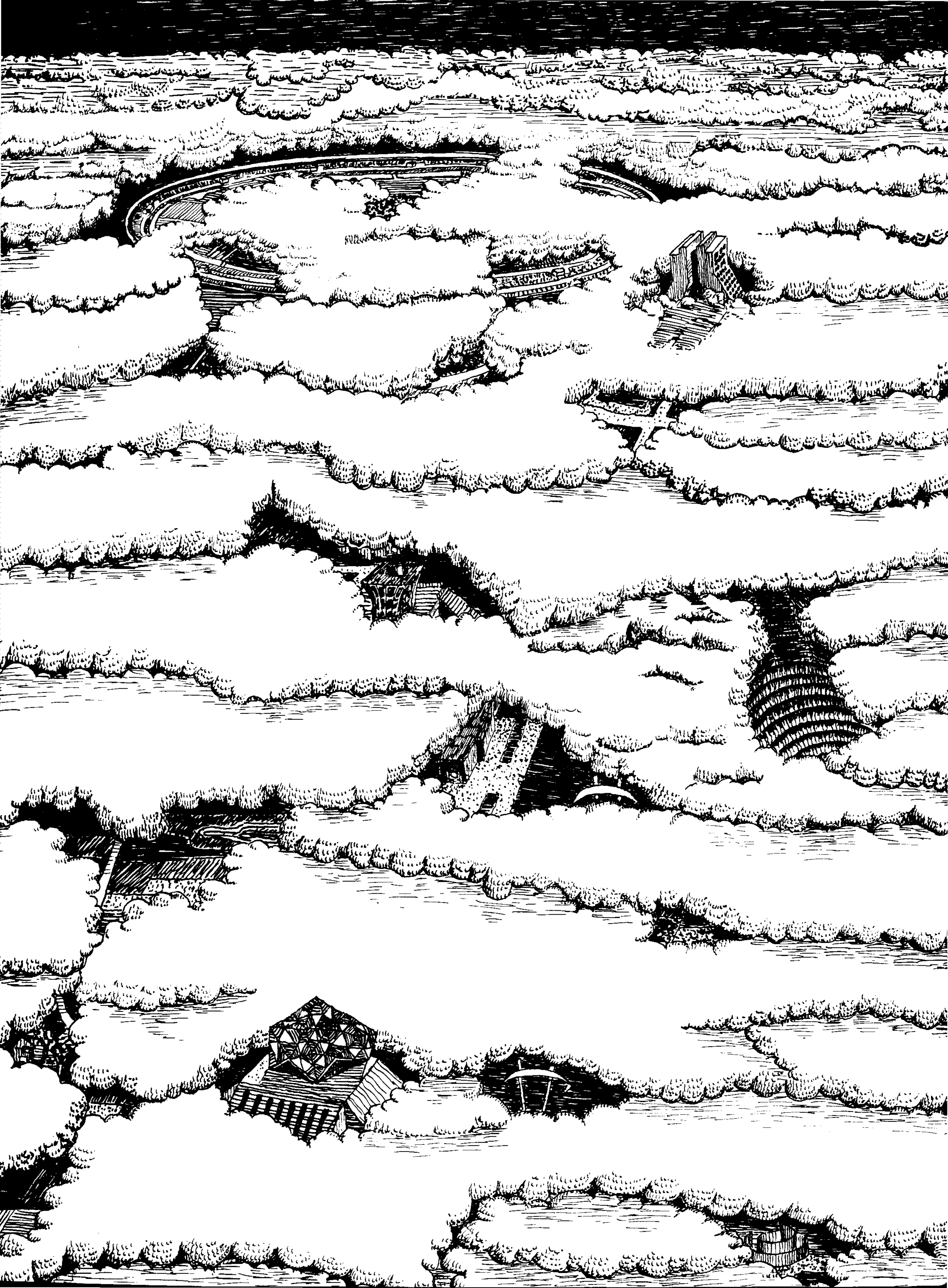


What about some of the other problems that are normally associated with raising a baby? BEBC was naked for a long time, whereas the 15 Foot Bubble Chamber was dressed up already with an External Muon Identifier. This was to the pleasure of some of its admirers, whereas others found the dress superfluous. It was first nourished with watery stuff (H_2 and D_2) then getting something more viscous to eat (Ne) and even metal plates were forced down its throat. Eventually it was "fenced in" by an Internal Picket Fence and (at the very end) got a nice sunburn and blisters, say micro-bubbles, that were produced by a laser beam. All these treatments helped to form a respectable, valuable, and productive adult.

We all got, in some way, attached to our equipment, but what is even more important, we all became associated with each other. I think many of us made friendships for a lifetime, enjoyed working together, sharing problems, accepting challenges. I consider myself very fortunate to have participated in this enterprise and I thank all of you for the warm hospitality and pleasant atmosphere I have always found at Fermilab.

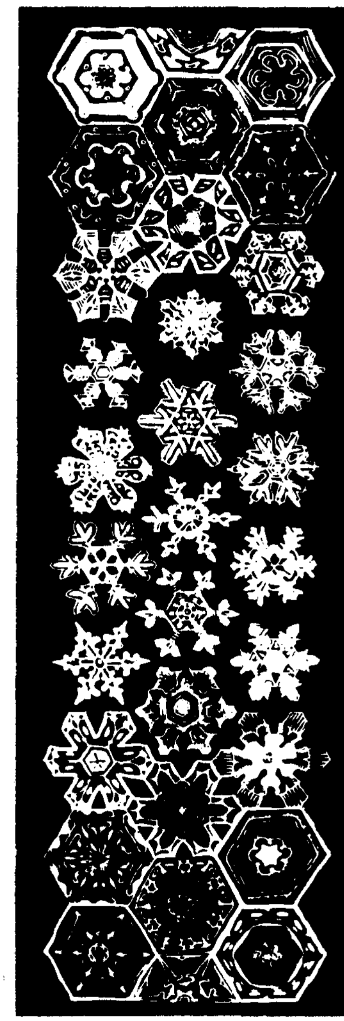


**Vater werden ist nicht schwer,
Vater sein dagegen sehr.**



George Snow

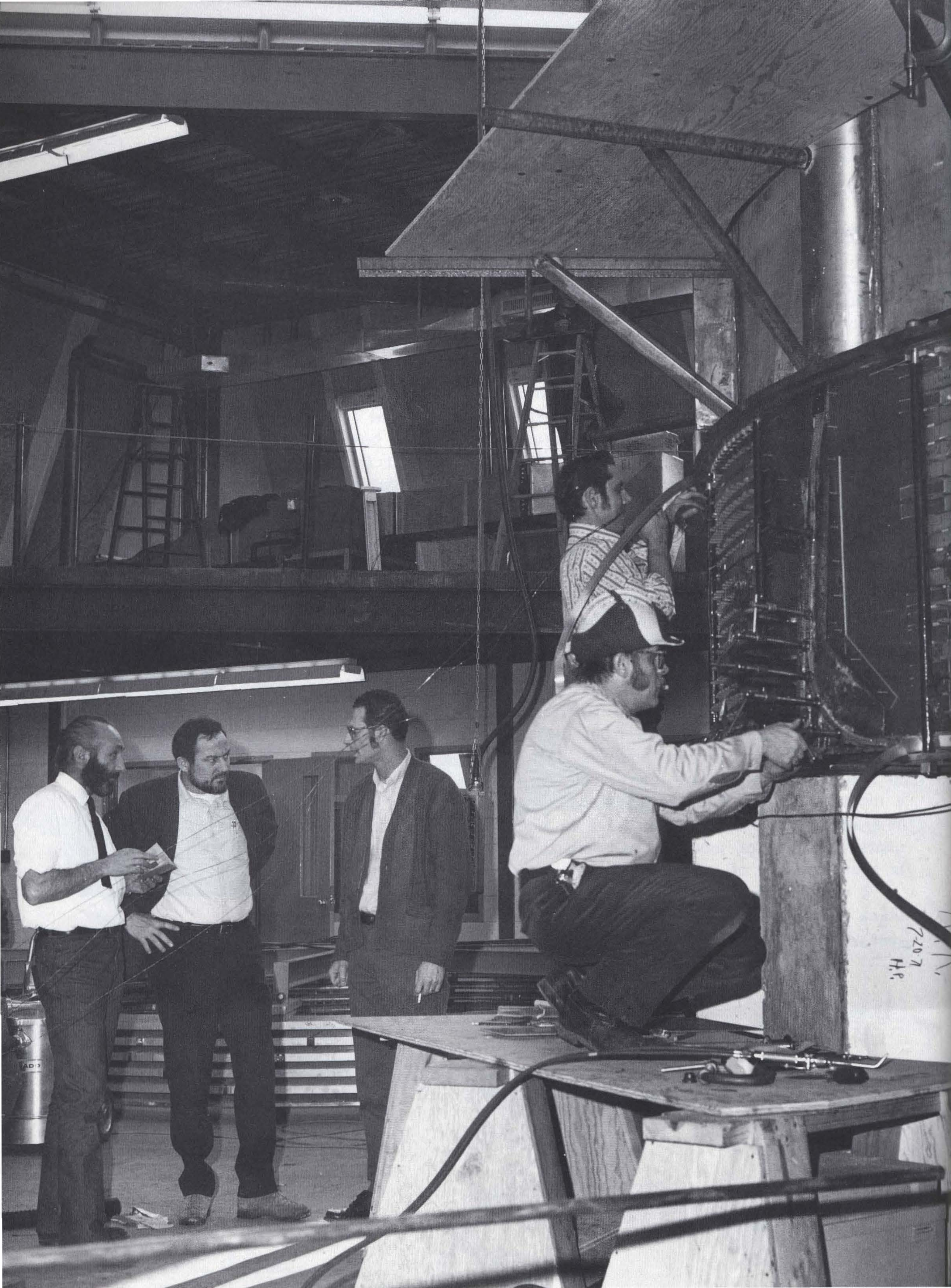
University of Maryland



First, I would like to reiterate Charlie Baltay's comments as a user. I really owe a great debt of thanks to my collaborators, to the designers and the builders, and to all the people who worked on the shifts to keep that 15 Foot Bubble Chamber going. I'm also happy that my experience with the 15 Foot made me a champion at Fermilab. I think I won the record for the longest delay between proposing an experiment and actually getting to do it. This was because I was in the box labelled neutrino/deuterium. For a long time I thought that Fermilab's deuterium was really being stored as a reserve and last resort that Bob Wilson could use in a fiscal emergency to trade for some accelerator magnets and that it would never be used to do physics in the bubble chamber.

Eventually, we had a very successful run and I really owe a great deal of thanks to all of you for making that possible. Actually, some of the problems that we raised in our physics proposal are still unanswered and some of the results that were published (as recently as this year) are still relevant. So, the administration did have some foresight in letting the neutrino deuterium program go forward. It turns out that some of the data that comes from those experiments is useful in P-bar P collider physics analysis. For example, if one wants to try to determine how many neutrino families there are from a measurement of P-bar P collisions by looking at how many W's and Z's it produces, you have to know something about the quark structure of neutrons as well as protons, and deuterium is a unique way of looking into that problem.

I would like to thank you again for this opportunity and thank Thornton for organizing it.



Malcolm Derrick
Argonne National Laboratory

I guess I can cap what George Snow has just said. We were supposed to do anti-neutrinos and deuterium. We're still waiting for the pictures! That was due to a minor accident, something to do with a nuclear emulsion stack in a stainless steel box coming loose from its mounting inside the Bubble Chamber. The bubble chamber piston could have pushed the bolts against the domed windows of glass. Fortunately, that didn't happen, but the bubble chamber run was terminated because of that accident. This was one of the very few occasions when one of these large bubble chambers (the 12-ft. bubble chamber at Argonne, BEBC, or the 15 Foot Bubble Chamber) really had a problem that caused the termination of a physics run, and it was not connected with the bubble chamber itself.

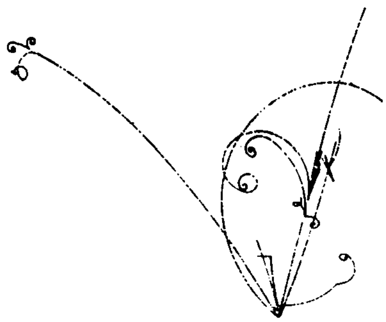
The thing that impresses me most about these large bubble chambers is that they have been unsurpassed for the excellent collaboration and cooperation between physicists, engineers, and the outstanding technicians who have operated them. These were like enormous bombs: one or two tons of liquid hydrogen. If ignited, it would create quite a plume. It never happened. Modern colliding-beams detectors are much more sophisticated than these old bubble chambers, although the new detectors are much less demanding in terms of required engineering integrity.

Tom Fields asked me to come and say a few words on behalf of Argonne. There has been a good interaction between Argonne and Fermilab over the years in the development of bubble chambers. The 30-in. bubble chamber, as many of you will remember, was operated at the Argonne Zero Gradient Synchrotron for a number of years and then, after being moved here, was the first chamber to do an experiment at Fermilab. When the 12-ft. bubble chamber was operating at Argonne with the large superconducting magnet that John Purcell built, Russ Huson and his colleagues were looking into how to build a bubble chamber of the magnitude of the 15 Foot in a laboratory where the resources were very pressed due to the accelerator construction and the incredible number of other experiments that were being done at that time. Russ got help from Bob Watt (who built the expansion system) and from John Purcell and the Argonne Staff (who built the 15 Foot Bubble

Chamber magnet). It was a very good example of project cooperation between the two laboratories.

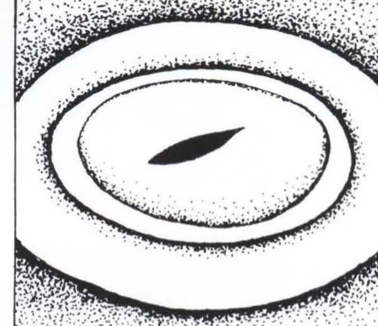
John tells me that the magnet actually quenched one time. I remember very vividly when we built the first 10-inch-diameter, 45 kilogauss superconducting magnet for the helium bubble chamber, which was the thing referred to in Bill Wallenmeyer's telex [see Appendix B]. When we first quenched (it was of course always at 3:00 am on a very hot and humid day), there was a terrific plume of something that came up from the vent as all the helium came out. This was immediately followed by a great cloud of dead insects falling down all over us after they had been frozen to the roof of the old barn that we were doing the experiment in. It was really something. I mean there was a bang! and this thing went off. And of course, when we took the chamber apart, we found that the vacuum can containing the coil was more of a spherical pill box shape instead of being flat. We learned a lot of things from that incident. One of the them was to try to design the magnets so that they didn't quench. The subsequent design of the 12-ft. bubble chamber magnet was so conservative that, in fact, it never quenched, even though it ran at Argonne for ten years and subsequently for five years continuously at SLAC. I guess John Purcell was a little more adventuresome with the 15 Foot Bubble Chamber magnet. It quenched once. These large magnets have still not really been surpassed in terms of the performance of the field volume and the stored energy, even though they were built twenty years ago.

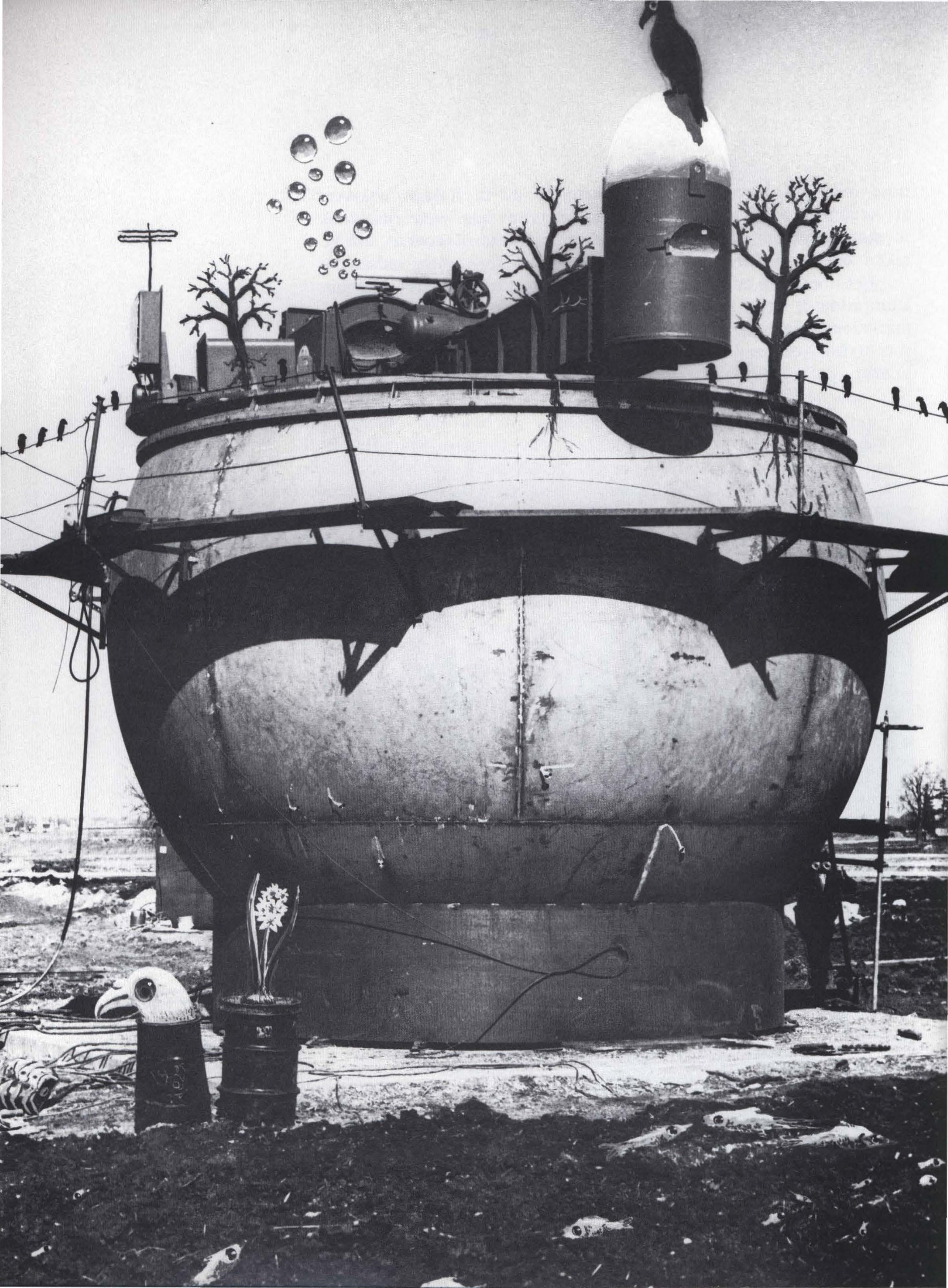
Earlier, Russ Huson referred to something I said about operating these chambers with neon. I don't remember all the details, but I do remember that we had a very vigorous discussion in the advisory apparatus at Fermilab about the large bubble chamber program. At that time, there was talk of a 25-ft. bubble chamber shaped like a football. Twenty five feet in major axis and I don't know how large in minor axis, but it must have been close to 15 feet. That was the chamber that I think I said something about having some difficulties operating with neon. I may have been wrong, but it was never built so we'll never know.



After the magnet, the final thing to be built was, of course, the chamber. We all know that the chamber was really 11 or 12 feet in diameter, but then there was this marvelous Wilson Nose sticking out between the magnet coils which allowed Bob to say that it was a "15" Foot Bubble Chamber. The chamber nose made it three feet bigger than the 12-ft. bubble chamber at Argonne, but I'm not sure how many events were analyzed in that particular part of the chamber. It can, of course, all be taken out in software!

Let me just conclude by reiterating again the tremendous admiration I have for all the people involved with these marvelous pieces of engineering which operated so successfully, so reliably, and so safely for a large number of years.





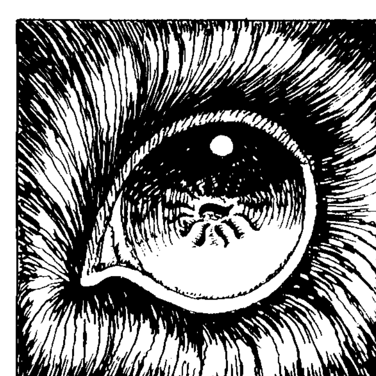
Frank Nezrick

Fermilab

As a user and as an early developer of the neutrino-bubble chamber facility, I wish to express my appreciation to those associated with the 15 Foot Bubble Chamber operation during its lifetime. I would like to add to these festivities by sharing a few memories from the very early years.

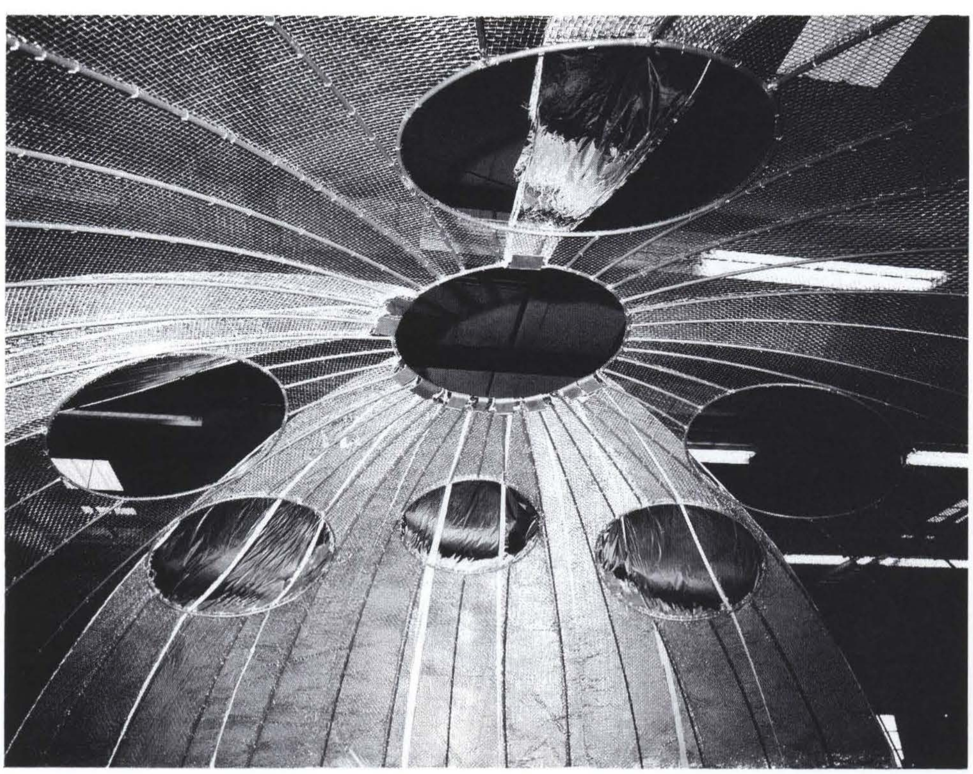
In my mind, the parents of the 15 Foot (those who produced and nurtured the embryo then called the 25-ft. bubble chamber) will always be Ned Goldwasser and Bill Fowler. Soon after I arrived at the Laboratory in 1968, Ned recruited me as courier and negotiator between himself and Bill (who was still at Brookhaven National Laboratory) in order to complete the proposal for the 25-ft. bubble chamber. The first large, really modern-age bubble chamber (ironless superconducting coils, fish-eye optics, etc.), the BNL 7-ft., was just coming alive and its successes were being incorporated in our proposal. Later the 25-ft. proposal went through endless reviews by the user community and the U.S. Atomic Energy Commission. It was at one of these meetings which Russ and Malcolm alluded to earlier where Malcolm, in a very passionate presentation, essentially shot down the 25-ft. bubble chamber by generating an argument which highlighted the problems with the chamber's resolution and distortion. Out of the ashes of the proposal for the 25-ft. bubble chamber rose the proposal for the 15 Foot Bubble Chamber.

One thing that has always impressed me over the years is that there is a closeness in the international community of neutrino bubble chamber users. Many physicists who were involved in the CERN heavy liquid bubble chamber - neutrino program in the 1960's were also involved in the 15 Foot program. A literature search of this physics would trace many members of this community intertwining, via visitor programs, sabbaticals, postdoc positions, etc., from the Ramm Chamber at CERN in 1963 through Gargamelle, BEBC, on across the Atlantic to the 12-ft. at Argonne National Laboratory, and finally to the 15 Foot Bubble Chamber at Fermilab. There was a closeness there between the bubble chamber physicists, but there was also a very strong competitive feeling.



Charlie Baltay described the matrix approach to picking an experiment in the early days of the 15 Foot. Each matrix element represented a different combination of chamber liquid and neutrino beam type. Proposals were submitted for every matrix element which might be available in the near or distant future. The Physics Advisory Committee (PAC) also made approvals based on this methodology and eventually filled the matrix with approvals. At some point the PAC realized that they had approved experiment E-155 as a group to develop the External Muon Identifier (EMI) for the 15 Foot. The group was hard at work, but the group did not appear in the approved physics matrix. So in a clean administrative attempt to solve this problem, the PAC made the "recommendation" that experiment E-45 be informed that 100,000 pictures of their exposure would be turned over to E-155 within six months after obtaining them. E-155 could extract whatever physics they wanted from the film and the EMI. That encouraged the marriage of the two groups into a single collaboration. This experiment, even with its enlarged collaboration, only received 120,000 pictures in its entire lifetime.

The other memory I wanted to share related to the Soviet/American collaboration on experiment E-180. In 1972, a special annex (Annex II) to cover the U.S.S.R./U.S.A. high-energy physics protocol was written to cover collaborations between the two countries that perform neutrino bubble chamber experiments. I have a thick book of the drafts of Annex II and related letters. A collaboration was formed between Fermilab, the University of Michigan, ITEP in Moscow, and IHEP in Serpukhov to study antineutrino interactions in a hydrogen-neon fill of the 15 Foot Bubble Chamber (another physics matrix element). Progress on Annex II was slow. Before Annex II was completed, the experiment (E-180) was proposed by the experimenters and had been approved by Fermilab (at that time the National Accelerator Laboratory). However, two collaborations were approved, each for 50,000 photographs, to do essentially the same experiment: antineutrinos in hydrogen-neon. This was to be a sort of contest related to the best neon-concentration and speed of analysis with the winner continuing with the experiment and the loser quitting and going away. Some hot letters were exchanged between the U.S.S.R. State Committee of Atomic Energy, the U.S. Atomic Energy Commission, and Bob Wilson. The next version of Annex II, which was a very general document, had buried in Article I.2 paragraph 1 the following statement for experiment E-180 (verbatim translation). "Parties will conduct studies...having in mind...not less than 500 thousand photographs." Bob Wilson wanted to hedge on that. Correspondence ensued between Chairman Petrosyants (U.S.S.R.), Chairman Schlesinger followed by Chairman Ray (U.S.A.), and Director Wilson. When the dust settled, the signing of Annex II was held up pending the exact interpretation in English and Russian of the phrase "having in mind." The interpretation problem was resolved in a letter from Chairman Schlesinger to Chairman Petrosyants with a concession from Wilson that if E-180 did not work out "...Dr. Wilson expects to try to find some other area of the neutrino bubble chamber research in which at least 500,000 pictures could be available..." The letter concluded with "I believe we can both agree that such an interpretation is most logical." Well, if I look up experiment E-180 in the 1988 Fermilab Research Program Workbook, it does not quite say Wilson "had in mind" 500,000 pictures. It does say "with the expectation that the experiment will involve a total of 500K pix." After all this, the experiment received only 273,000 photographs and is listed as "inactive." I don't think we should ask for the rest of the pictures, in fact I think we should "have in mind" terminating at this point.



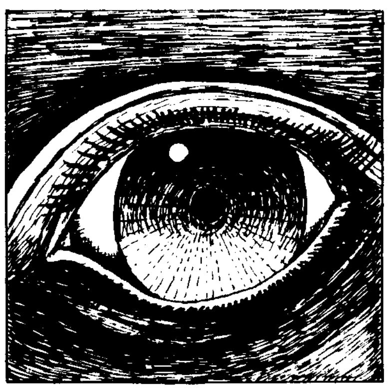
Jim Ellermeier

Fermilab

When Thornton asked me if I'd say a few words today, I asked him what he had in mind and basically he thought it would be a good idea to have someone who has been through the trenches say a few words. So I guess this talk is given by someone who's been in the trenches to those who were in the trenches with him.

First of all, there seems to be a misconception about exactly where the 15 Foot Bubble Chamber was. If you got instructions to go to the bubble chamber, the person giving the instructions would probably say something like, "Just go to the end of the neutrino beamline, Road A. There is this strange-looking building down there and it's got this really weird-looking roof on it. That's the 15 Foot Bubble Chamber." People would walk into the building and ask, "Where's the bubble chamber?" We'd say, "You're pretty close to it, but actually you're about 200 feet away." A lot of people were very confused by that. Other people might ask, "What do you do at the bubble chamber?" and still others would answer, "They've got this huge sphere of 10,000 gallons of hydrogen that has this piston in it. They pulse it up and down and they shoot particle beams through it and take pictures." In point of fact, that is pretty close to exactly what went on out there. It's really kind of hard to describe all that went on at the Bubble Chamber. People would ask, "What do you do there?" and we'd describe what it was that we did and the longer we talked, the more confused they got. Eventually I just simplified my answer to, "I work at Fermilab" and that would suffice.

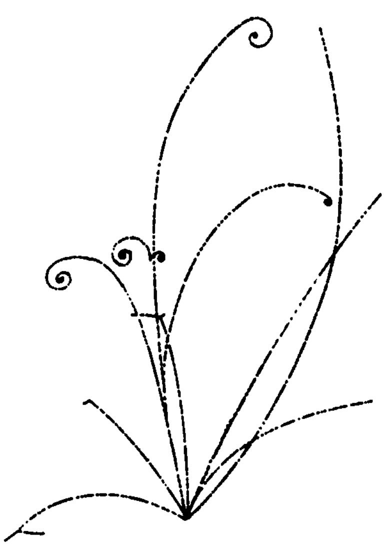
Basically you had to be a jack-of-all-trades to work at Fermilab. You had to know a little bit about electronics, hydraulics, mechanics, cryogenics and vacuum systems, and if you could master a few of those, you could do pretty well as a bubble chamber technician. During the interview for a job at the 15 Foot Bubble Chamber they'd ask you a lot of questions, but you had no idea what they were talking about. You couldn't even fake an answer for a lot of things. When interviewing, they always asked two questions. The first one was, "Are you willing to get your hands dirty?" After you'd been hired you knew what that really meant was, "Are you willing to overhaul compressors?" The second question they always asked potential employees was, "Are you willing to



work rotating shift work?" After a while, you knew that this question should be interpreted as, "Are you willing to work midnights on only two hours sleep?"

Shifts always rotated when we were taking physics data and that was an extremely tough time for a lot of people. Most people thought midnights were definitely the worst shift. I remember my first set of midnights. I had only been at Fermilab about two weeks and they said, "We're ready to start shift work." I said, "Here it comes." My shift was the one that was going to start at midnight so I came in at a few minutes before 12 after only two hours sleep, and John Stoffel, the Operations Chief, said to the crew, "Our assignment for tonight is to stack zinc in the vacuum space." (Bob Ferry was the Crew Chief and Jack Rossetto and Del Wilslef were there.) I said to them, "I don't know what that means, but let's hit it." So, we walk down to Lab B and the building was literally full of pallets stacked with slabs of zinc which were about 18 inches long, an inch and a half thick, and 4 inches wide. We spent the next set of midnights putting that zinc into the vacuum space. Seven midnights and 60,000 pounds of zinc later, we completed the job. I'll remember that for the rest of my life. I said to myself, "If this is high-tech, then Fermilab is not the place for me."

When most people think about the 15 Foot Bubble Chamber, they probably remember particular events and situations they were involved in and the people that they worked with. One of the big things that comes to my mind was the time that the chamber piston seized. The cap fell off of the emulsion box and became lodged at the side of the piston. We were taking pictures and all of a sudden we couldn't expand the chamber. It took some time before we figured out what was going on. We had to completely disassemble the device before we really knew what the problem was. That was a big job and a lot of work for a lot of people.



As previously mentioned, we tested the integrity of our magnet only once. I happened to be there when it happened. There was a young technician on top of the chamber at the moment it happened and he must have thought that the end of the world was coming. When that rupture disk went, the noise was simply incredible and the vapor cloud went all the way to Casey's Pond. The lab behind us called the Fire Department because they just knew we'd blown the place up.

A lot of us remember the old hydrogen compressor, better known as the Red Lemon. What you had to do was overhaul that thing at least twice a week, typically on Sunday afternoon, so everyone hated Sundays. If you got to be lucky enough to double back, that was your gift for doubling back on our shift. Doubling back meant that you worked till midnight, then came in at 7:30 the next morning and got to overhaul the Red Lemon compressor. Then there were the stainless steel plates. A lot of us spent a lot of time polishing and grinding them so that they wouldn't boil in the chamber. The expansion system; a lot of us spent a lot of time down in the pit fixing oil leaks. There was nothing worse than working in Lab B and seeing a mist of oil coming from the expansion system because you knew exactly what was going on. There were so many improvements made on that system in the last few years that many of the newer technicians didn't really remember what it was like to have to work on that expansion system constantly.

Working in Lab B was always a "joy" too. It was hot in the summer and cold in the winter. We all can remember stacking up the expansion system in the pit and going through lots of long hours, particularly on midnights, putting that expansion system together. The original crew at the bubble chamber that started the cooldown in June and July of 1973 was made up of experienced people, mainly from Brookhaven and Argonne. Some of these people are still here at the Laboratory. The leaders at that time were George Mulholland and Hans Kautzky, and the emergency forces were Carl Pallaver and Paul Thorkelson. The crews consisted of John Stoffel, Asa Newman, George Athanasiou, John Foglesong, Bob Stover, Stan Tonkin, Denny Curtis, Bill Noe Sr., Dick Almon, Jim Kilmer, and George Simon who just retired from the Laboratory about a year ago. Then there was Frank Bellinger, Johnny Colvin, Colby Pitts, Gene Beck, Ron Davis, John Woodworth, Mike Morgan, Bob Ferry, Jim White, Jerry Kadow, Steve Johnson and Chuck McNeal.

These particular crews accomplished many "firsts" because they were the first crews to cool the apparatus down. The cooldown of the chamber started on June 23, 1973, and they had the first liquid in it nine days later on July 2, 1973. The chamber was full and controlling seven days later with no problems at all. This was quite an accomplishment given that it was all being done for the very first time. There weren't too many hitches. When we first started keeping our log books, everything went into a green log book. I'm sure that anyone who's been around the chamber has certainly seen some of them. It's ironic, but we went though exactly 100 of these green log books in the fifteen years that the bubble chamber operated. We finished our last run using log number 100.

In our 15 years of operation, we had only one woman technician who worked at the bubble chamber. She was only with us for about a year and a half. In addition, we certainly depended a lot on our other female support staff, our secretaries Marion Richardson, Elsie Renaud, Denise Augustine, Norma Johnson, and Bert Forester. Bert started about two weeks before I did and Bert worked at the bubble chamber for over ten years. She left about three years ago and was replaced by Claudia Foster who stayed about a year.

Then of course there were all our welders and machinists, Larry Bingham (our first welder), Mark Krueger, Ivan Stauersboll, along with Sam Alexander, John Ramus, and Don Fisher who replaced Sam when he retired about ten years ago. Then we had a member of the crew out there that was always on midnights, even when we weren't working shift work and that was Dave Lyden. He'd call you at home because something was wrong and he'd do just about anything to fix the problem, anything except dump the fluid out of the chamber. We appreciated him a lot.

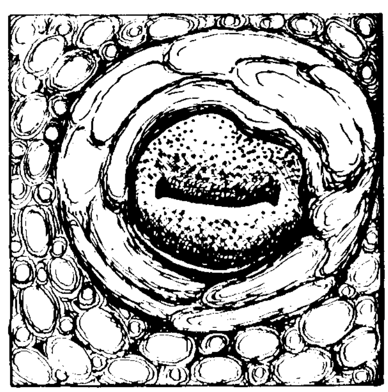
We didn't work all the time. We also had some fun. One of the things that was very enjoyable was the bubble chamber softball team. We were just a rag-tag bunch of guys who got together every once in a while to play ball and always had an annual game against the Accelerator Division. I don't know how that series came out, but I'm sure the bubble chamber ended up winning more games than the Accelerator did. Bob Pucci was always our pitcher and we'd leave him in until he'd start walking runs home, then we would punish him by yanking him out of the game onto the bench and putting someone else in. They probably did worse than he would have, but we thought we had to do something about Pucci. George Mulholland, Wes Smart, and Jim Kilmer always cringed when they knew it was time to play a ball game because you could guarantee that the next day at least half of the crew had something wrong with them. George, Wes, and Jim would go around and make a health check on everybody and, at best, you were probably stiff and sore for two or three days after.

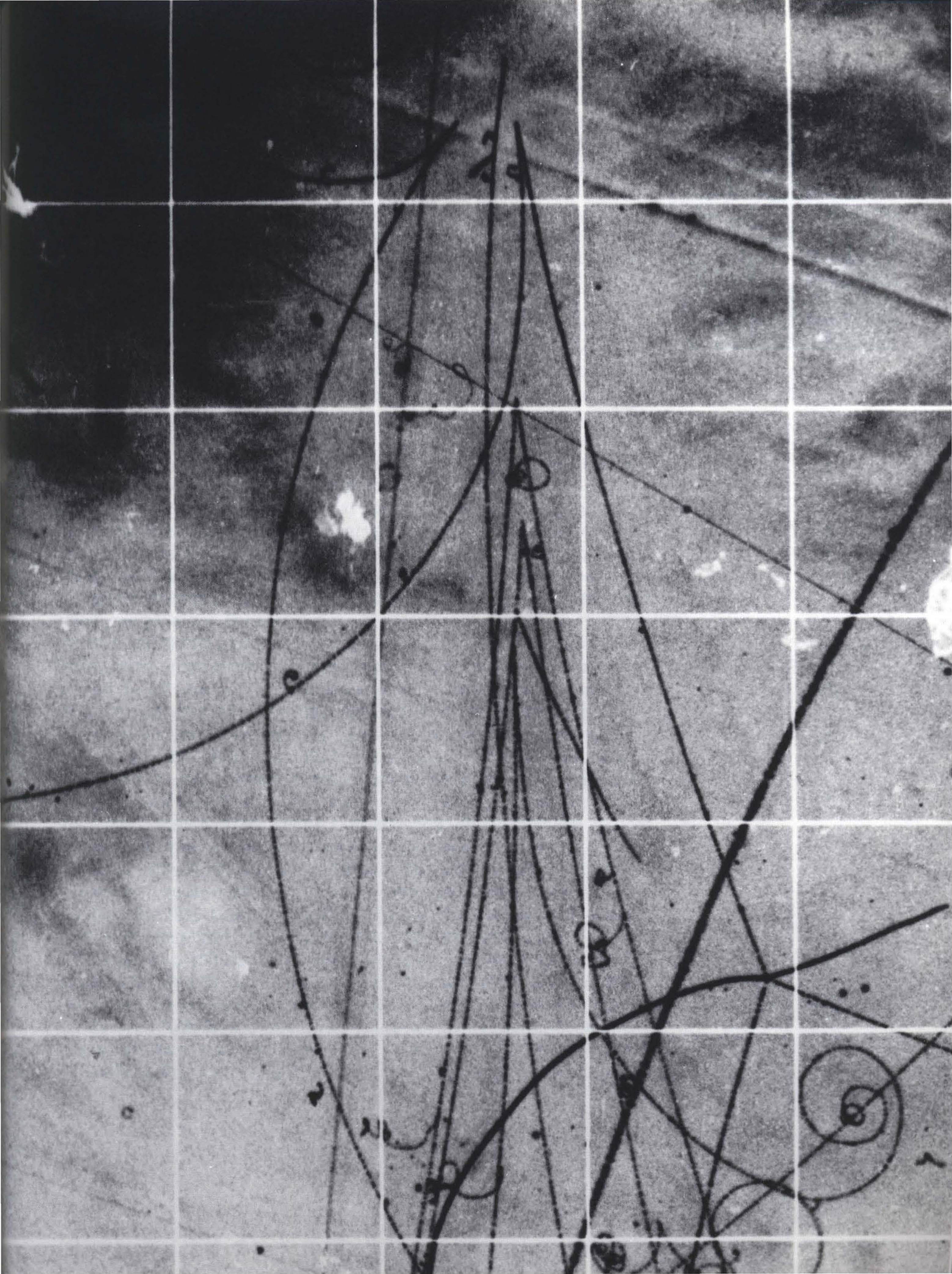
Although there were a lot of muscle pulls and a number of broken fingers, we sustained a lot more injuries from what we called the "post-game festivities." If we had refreshments at the game, it would continue there after the game until it got dark, then we'd adjourn to the Users Center. We always felt this driving obligation to make sure that the Users Center closed on time and most of us saw that that happened.

We had six people that retired from the bubble chamber in 15 years. They were Stan Tonkin, Sam Alexander, Asa Newman, Harry Stapay, Paul Thorkelson (who is in Florida), and George Simon. Paul Thorkelson, for those that are interested, sent a letter and it's in the sign-up book. He regretted not being able to come.

I would like to make a comment about safety. I think that the technicians really deserve a lot of credit for keeping that place as safe as it was for 15 years. I remember one of the meetings we had right before this last run. Thornton was talking to us and he said "I think this last run ought to really go off with a big bang." Then he said "Wait a minute, wait a minute, no, no. That's not what I meant. I think you get the idea, but let's not do that."

In closing, I would like to give some credit to the wives and families of all the guys who worked at the bubble chamber over the years. We know that working on a rotating shift is very hard on the technicians, but it is very hard on the wives and families, too. There were a lot of things that we had to give up and miss; a lot of anniversaries, a lot of school functions, a lot of sporting functions that we just weren't able to attend. Because it was a big sacrifice for the family, I think in appreciation of their sacrifice, I would like to say thank you to them. I think they deserve a round of applause.





Douglas Morrison

CERN

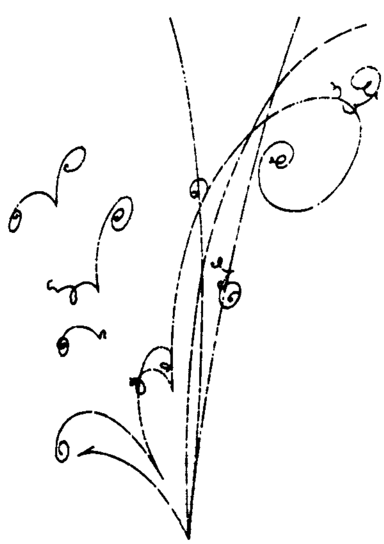
Since I am the last speaker, the obvious thing is to be brief. As was mentioned previously, we (experiment E-632) were the last experiment. It was a typically international experiment with eight European groups, two Asian Indian groups, and six American groups. The thing that was different about our experiment was that we had holographic optics which involved the Bubble Chamber Group in an enormous amount of work. They had to add many mirrors and things in different places, but finally, it all worked out very well. The proposal was made in 1980, and the run took place between 1985 and 1988. We've gotten our film and measurement data and now the goal is to measure and analyze the data into the 1990's.

For myself, I've always loved track chambers. You have a certain extra feeling if you can actually see the events one by one instead of just having some numbers to play around with. With track chambers you could really see the tracks, you felt much more intimate with the events and the physics. I started out with cloud chambers and then in 1956 (at CERN) we started the 10-cm. chamber, then moved on to the 30, 80, and 150-cm. chambers. These were followed by the 2-m bubble chamber and BEBC. And, of course, as time goes by you tend to improve things, making them more reliable. It's interesting to compare these CERN chambers to the 15 Foot Bubble Chamber, now that everything has become very "high-tech." When I first started experimenting with cloud chambers and the early bubble chambers, the devices were very simple. If you wanted some liquid hydrogen, you simply brought in a little dewar and you worked with a transfer line which was just a rubber hose. It was fine with the hose on, but if you took it off it was cold and it was solid. So the only thing to do was warm it up. But there was nothing safe to warm it up with except your hands, so we used to warm the hose up with our hands.

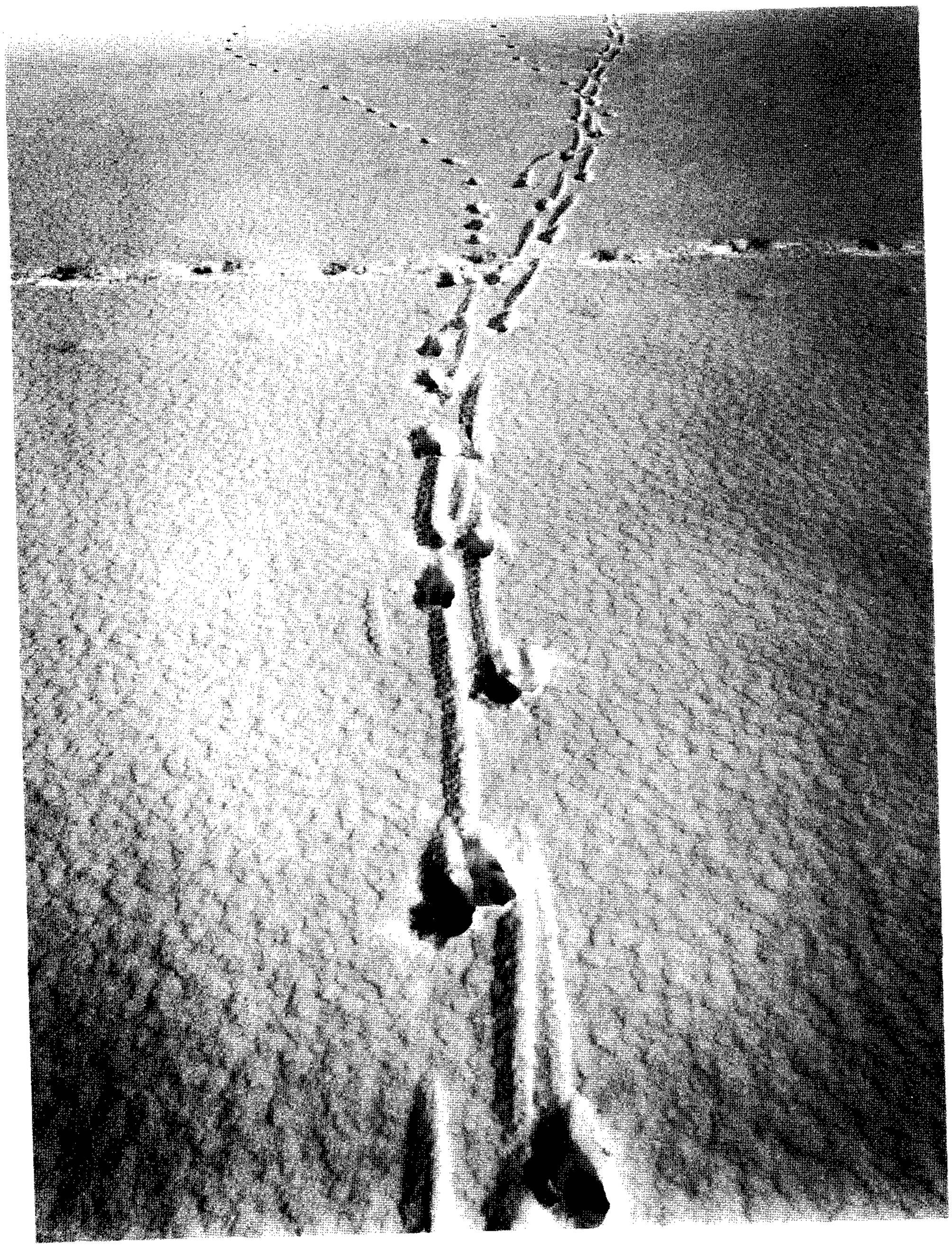
About what Gert Harigel was saying about the BEBC Bubble Chamber being exceedingly reliable and working very well, it's really a question of what is the perfect chamber. The 15 Foot was a very good chamber, but it was somewhat different than BEBC. It's like the story of the man who was looking for the perfect wife. He went round everywhere looking for the perfect wife and he'd meet a lady who was great but not quite perfect, then another one that was great but not quite perfect.

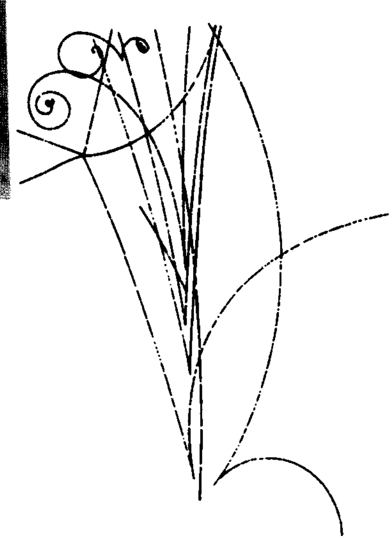
It was a very interesting search. The man went on and on and on until finally, ultimately, he found the perfect woman. There was only one problem, she was looking for the perfect man.

BEBC was incredible! I mean, you would make a running schedule out, you'd arrange your life, you would go there, do your experiment and come away again. At Fermilab, it was somewhat different. You had a much more interesting time. The result was that you stood back and admired BEBC, it was really magnificent. On the other hand, when you worked with the 15 Foot, it was much more a part of your life. Some things worked well, some didn't. You worked hard, you repaired things, and it was a team effort. Because of this the physicists felt much closer to the crew in a sense. With BEBC, when you were on shift you'd talk with the crew and you'd go in and watch football games on television and drink a glass of wine with them. At Fermilab, it was somewhat different. When you talked with the crew it was usually about work and only occasionally about something like the Chicago Bulls or the Chicago Bears. One time I was talking to one of the crew members who told me that he had left Chicago to live in California for a while. I asked him, "Well, why did you come back, it's wonderful in California." He said "Well, yes, it was nice, but you know, there's something about Chicago and working here at Fermilab." You know, I've been here long enough that I understood what he meant. Yes, it's tough working here, it's tough working on the 15 Foot, the Chicago weather is very hot then very cold, but nonetheless in time, it becomes very attractive. It seems like part of your life and you really appreciate it.



So the closing of a bubble chamber is always sad. These things happen. But on the other hand it always means progress in high-energy physics. If you don't have something new, you're dead. You always have to go on and do something different. It was something like this with the BEBC closure. There was perhaps one difference. I organized a wine tasting just to make it a little bit different.....is there wine here? Yes, there is some wine. On the other hand, I think many things are very similar between the BEBC closing and today's festivities. There are some very nice people here. I'd like to thank them all, it was nice working with the crew. Yet there is one little thing that is missing from this festivity. So, I'll try and help to fill that gap. Here's a bottle of Laphroaig! It's the Scottish contribution. Laphroaig, if you can pronounce it, is one of the very best whiskies.



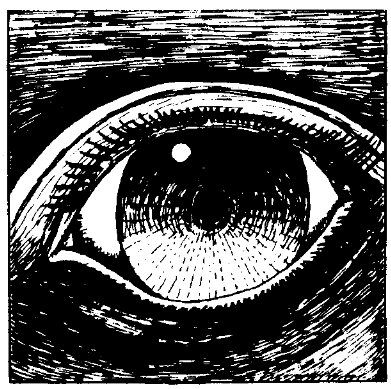


Leon Lederman

Fermilab

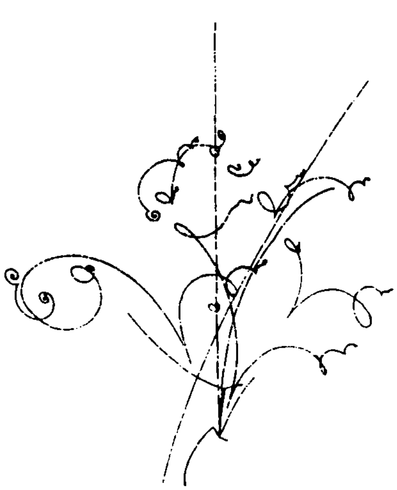
Ah, Laphroaig! Bless the Scottish contingent! I wanted to share with you some early recollections of the 15 Foot Bubble Chamber, but I forgot them. In fact I don't even know what I'm doing here. However, I do recognize that this is really the end of an era. Except for the one last bubble chamber that we still have here, this is the end of the bubble chamber era which started in the 1950's. Earlier speakers have talked about this and it is a very interesting piece of the history of particle physics, a 30-year period of an invention, the bubble chamber, which has been remarkably fruitful. Glaser's epochal idea was actually born while watching bubbles in the beer hall outside of the University of Michigan campus. However, it took a lot of work and ingenuity to produce some primitive tracks.

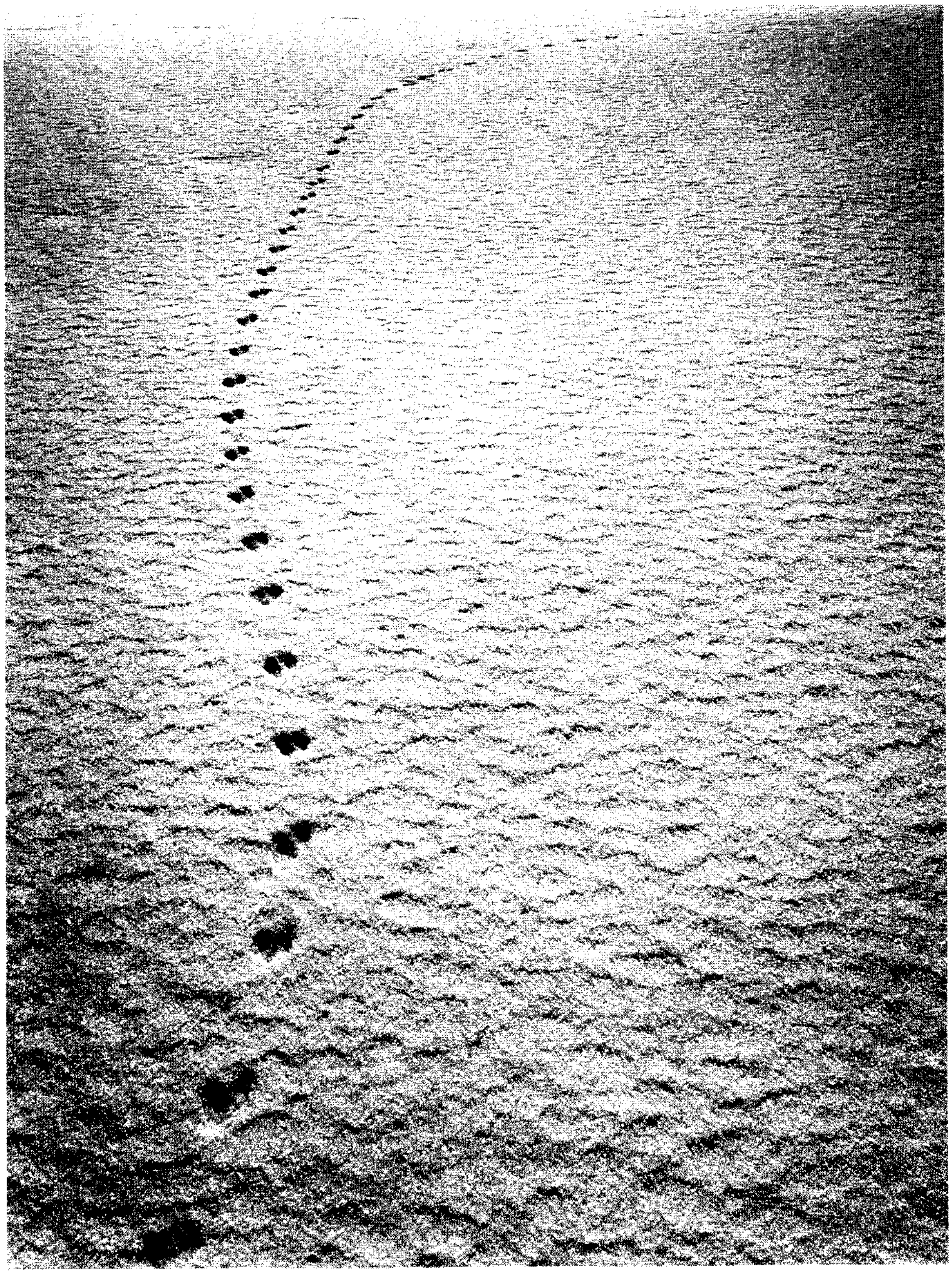
This was followed by the evolution and development of this fantastic instrument which carved its niche into the progress of physics. One of the many important things about it was the training of technical people. The professors who spoke here today didn't do anything, it was the graduate students who did all the work. And I know some of the graduate students because at Columbia we had some bubble chamber graduate students. Some of them weren't very smart. One of them, I especially remember, couldn't even find the bubble chamber. He looked at the pictures, but he never saw the bubble chamber itself. In fact, it came time for his final exam and his professor, I won't say who it was, was very nervous because he was not allowed to ask the questions. The other professors asked the questions. This bubble chamber student was pretty bad. The professor of the student was sitting in the back of the room, nervous, chewing his nails, and the rest of the team was looking at this kid. Finally one of them says to him, "Okay, we'll start you off with an easy question. What is the square root of 16?" And the student says, "Gee, I didn't expect that." He was studying about bubbles, so he sweats and he thinks, and finally he says, "Four" and the professor jumps up and says, "Give him another chance!"

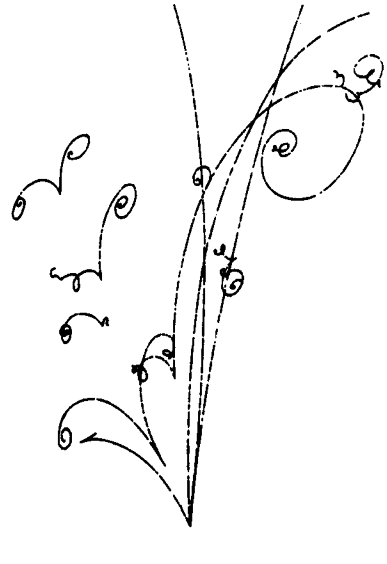


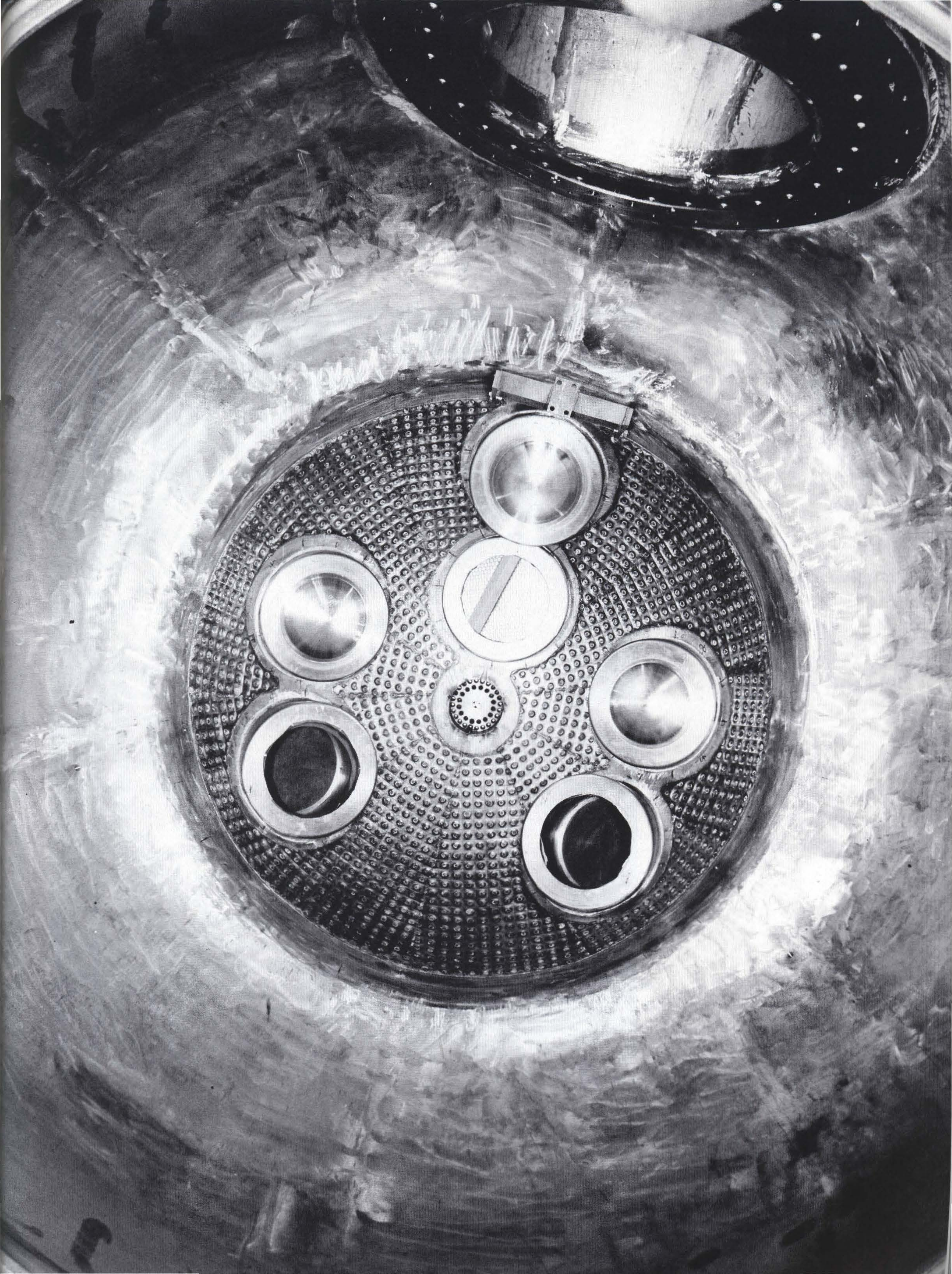
And then the Russians. We always worked with the Russians on the 15 Foot Bubble Chamber. I like that idea of the very tentative allocation: "I had 500,000 pictures *in mind.*" I have *in mind* a doubling of all salaries at Fermilab. With the Russians and physics everything is different now because they have Gorbachev and glasnost and this has spread not only in Russia but in Poland. In Poland they had a full page ad in the newspaper which said, "Put your money in a bank and we will give you interest." That's a new idea, that's really not socialism at all, it smacks of the other stuff. So this peasant walked into the bank and wanted to talk to the bank manager and he said, "I give you hundred zlotys and you give me interest, yes? How do I know it's safe?" Then the bank manager says, "Oh, it's safe, you know we are good bank, see the big walls, marble on the floor, big desks." "Yea, but suppose bank go broke." "Oh, can't go broke," the manager says, "we have insurance." "What's insurance?" So, he explains about insurance and he says, "Yeah, suppose insurance company go broke?" "Oh, insurance company can't go broke, it's backed by the City of Warsaw." "The City of Warsaw? Suppose City of Warsaw go (he looks in his phrase book) belly up?" And the manager says, "Can't do that, that's backed by the Polish Government." So he says, "Polish government huh? Well, suppose Polish Government got no more money." "Well, in that case comrade," he says, "we are supported by our colleagues in the Soviet Union." "Ah, the Soviet Union. Suppose they go broke?" And the manager says "Comrade, isn't that worth a hundred zlotys?"

If we have to get serious, the decommissioning of the 15 Foot Bubble Chamber, the last bubble chamber, is further evidence of how our field is changing. The technological progress is impressive but the sociology is something that none of us yet understand. If we look at the Collider Detector at Fermilab for example, we note that the large bubble chamber facility with its hordes of users did act as a training ground for the present-day sociology as well as the physics. The people who made it with bubbles, names like Alvarez, Steinberger, Goldhaber, Sandweiss, Baltay... just to name a few at random, didn't do too badly in the outside world. And so finally, in consolation I note that the Lab is not losing a bubble chamber but gaining a new contingent of physicists, engineers, and skilled technicians in the next phase of the battle for the ultimate theory of matter.





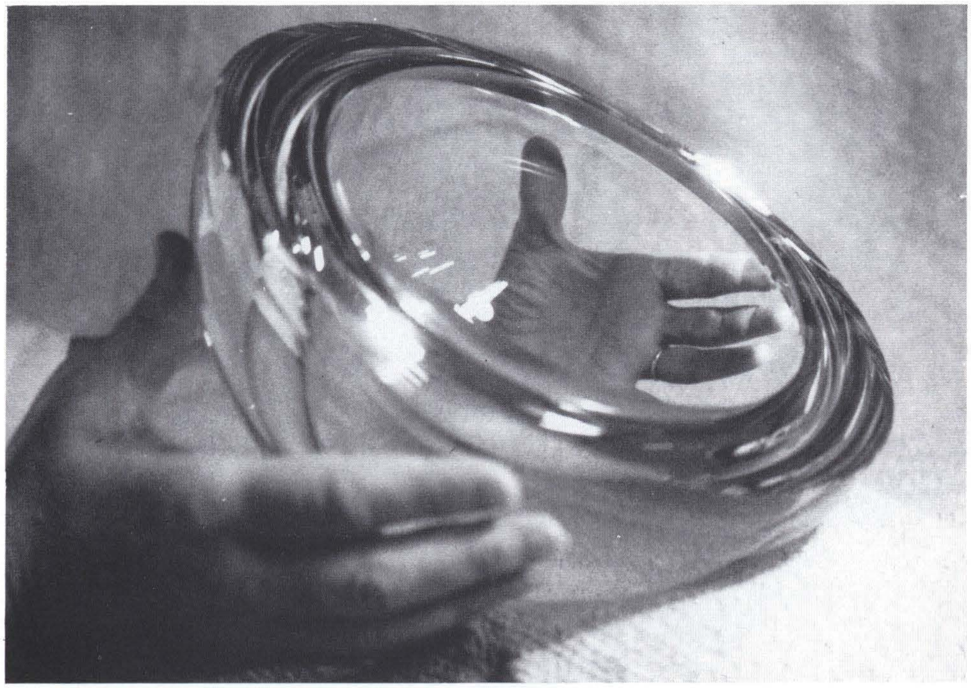


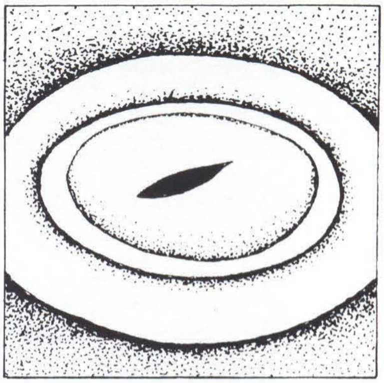


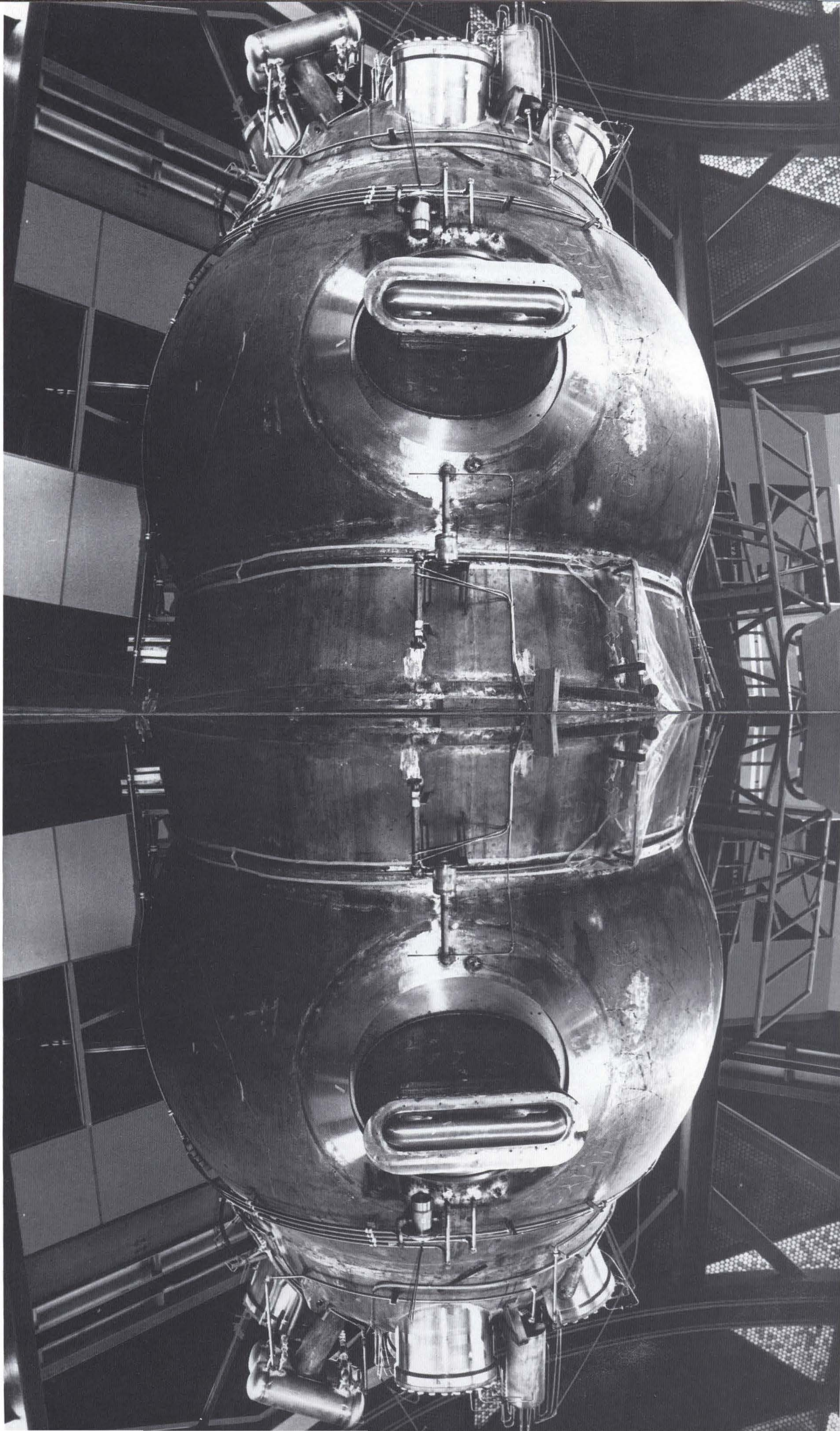
William Fowler
Fermilab

I'm happy to accept this plaque for those who are listed. I think I will refer to them as the workers. There is space, I am told, to add whatever names accidentally might have gotten left out. So, if you know of a name that needs to be added, please let us know. Many of the workers are here today, and I'm sure they deserve a lot of credit for producing the physics results that you've heard about from the other speakers. We probably were unable to produce Nobel-prize-winning results, although we still hold out hope for this latest experiment. But there certainly was no question but what we were trying very hard, and there was a good chance that neutrino beams from the Main Ring and later from the Energy Doubler would have made this possible. We'll wait and see whether or not that happens.

I would also like to emphasize that the 15 Foot Bubble Chamber crew, even though they were not quite like the astronauts riding the Challenger, were constantly dealing with equipment which required attention and a high level of alertness. And it's because of this dedication to the job that we survived all these years without a serious incident, and we are all thankful for that. Thank you very much for the plaque.





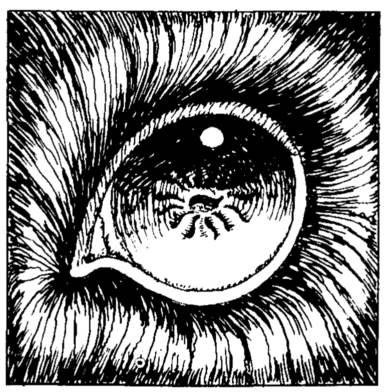


Reflections on the 15 Foot Bubble Chamber

To *reflect* is to remember a person or event with thoughtful and purposeful consideration. Webster says that reflection is the "Consideration of some subject matter, idea, or purpose often with a view to understanding or accepting it or seeing it in its *right relations.*" The key idea that concerns us here is captured in the nuance *right relations*, i.e., to view something in perspective. In this section entitled "Reflections...," another contingent of the people who played a prominent role in the conception, design, construction, operation, experimentation, and decommissioning of the 15 Foot Bubble Chamber reflect on their experiences with the 15 Foot.

Because of the contributions of Robert R. Wilson (then NAL Director) and Edwin Goldwasser (then Deputy NAL Director), we gain an insight into the process by which a very large laboratory support structure undertook to build what was then viewed as an extremely ambitious 15 Foot Bubble Chamber facility while under tremendous constraints in regard to building other major experimental areas and the NAL accelerator itself.

Another perspective that emerges from the contributions below is the retrospective question regarding the "value" or the "worth" of the 15 Foot Bubble Chamber program throughout its long history. Some of these topics were touched upon earlier in regard to unique physics contributions made by the 15 Foot in Charles Baltay's talk. We also saw in a veiled way (mainly through bubble chamber jokes) how a particular physicist's style for doing physics and his graduate training helped to determine whether he considered himself within the ranks of "counter" or "bubbler" physicists. Among many other things, these contributions briefly reflect upon the question of the value and worth of the 15 Foot Bubble Chamber program in an even more straight forward way than the presentations in the previous section.



The articles below differ from the last section only in that they were solicited "after the fact" from people who were not able to attend the 15 Foot Fest, yet each of these contributors were important to creating and recalling the history of the chamber.

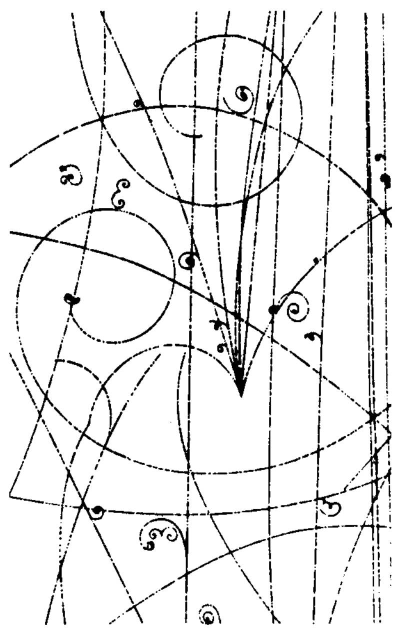

NAL SITE MGT.

William Fowler

Fermilab

From the beginning of the 200-GeV accelerator project it was fully recognized that a large hydrogen bubble chamber would be required for carrying out experiments. The use of such a device would be first and foremost for detailed studies of strange particles. The hydrogen bubble chamber is an ideal tool for this type of physics since both production processes and decay events are easily analyzed. The Ω^- particle had been found at Brookhaven in 1967 using the BNL 80-in. hydrogen bubble chamber exposed to a high-energy separated K^- beam. At NAL we all knew that higher energy beams of the various particles would open up a whole new range of possible processes to be studied. Another development was the implementation of the first accelerator neutrino experiments. This is now a timely topic since Lederman, Steinberger, and Schwartz won the 1988 Nobel Prize in Physics for the two-neutrino experiment at BNL, performed in 1962. This experiment and other accelerator neutrino experimental possibilities led to designs of hydrogen bubble chambers with sufficient volumes to observe neutrino events as early as 1963-64. Three such chambers were built in the late 1960s: the ANL 12-ft. bubble chamber, the BNL 7-ft. bubble chamber and the CERN Big European Bubble Chamber.

The NAL summer studies of 1968 and 1969 devoted a considerable effort to studying the requirements for an NAL bubble chamber and its associated beams. Ned Goldwasser and Jim Sanford played instrumental roles in organizing these efforts. It was at this time that a joint program between the Shutt bubble chamber group at Brookhaven and NAL was organized and a formal proposal for a 25-ft. hydrogen bubble chamber for NAL was prepared.

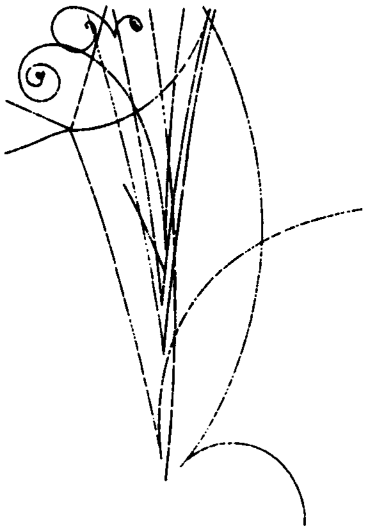


Following the denial of funds for this proposal in the fall of 1969, Bob Wilson decided that he could not afford to wait a year when the agency might be able to fund the 25-ft. chamber (the estimated cost of the chamber was $13,616,000). I was asked to join the NAL staff in January 1970. My job was to generate an alternate way of implementing a bubble chamber program at NAL. Several ideas were kicked around such as moving the 12-ft. bubble chamber from Argonne.

After a few months of evaluation of the various possibilities, the concept of the Fermilab 15 Foot Bubble Chamber was agreed upon. When this idea was presented to the user community, there was immediate and enthusiastic support.

The plan was that NAL would design and construct a new chamber with a linear dimension of 15 feet. Spherical vessels would be used so as to minimize the wall thickness, thus saving on the amount of stainless steel required. The volume would be 30,000 liters. Since the 200-GeV protons would produce secondary pions into a smaller forward cone than at ANL's Zero Gradient Synchrotron or BNL's Alternate Gradient Synchrotron, very intense neutrino beams would be produced. Another feature was to use earth as the muon filter rather than steel from battleships as had previously been used at ANL and BNL. The range of the muons in earth at NAL meant that the 15 Foot would be one kilometer from the target. Incorporated also was the concept of deuterium and neon fillings or neon-hydrogen, neon-deuterium mixtures.

One important decision was to try to develop a staff which could ultimately operate the chamber. In order to accomplish all the work during the design and construction with such a small operating group, it would be necessary to sub-contract much of the activity to other experts. Several of these are worth mentioning. Don Getz helped arrange for John Purcell and his group at ANL to be responsible for the superconducting magnet. John had done the major work on the ANL 12-ft. superconducting magnet and he and his group did a superb job in producing the 15-ft. magnet.



Peter Van der Arend and his company Cryogenic Consultants, Inc., of Allentown, PA, had carried out the cryogenic designs for the 12-ft. chamber. Peter joined the NAL 15 Foot program at the start and through his efforts and those of the other members of his company dewars, piping, valve boxes, cooldown exchangers, refrigerators, and compressor specifications and designs flowed steadily into the system. Peter's efforts continued all the way through commissioning and he was also involved in many of the improvements that were made during the life of the chamber.

Our friends at SLAC took on the responsibility of the expansion system. Bob Watt and his group, many of whom had worked on the Alvarez 72-in. chamber at LBL, had over the years developed techniques for handling the large forces and vibrations associated with the rapid expansion of the bubble chambers. Their design incorporated this experience and made it possible for the 15 Foot expansion system to function reliably from the beginning of operations.

The CERN BEBC optics design existed at the time the decision was made at NAL to build a new chamber. One of the first decisions was to incorporate the CERN optics design, which included the fish-eye windows and their mounting details. Russ Huson, Wes Smart, and the late Lee Mapallo were intimately involved in this tricky procedure.

During the whole period that I have been describing only one serious problem surfaced. The plastic piston for the 15 Foot failed during it's acceptance test. At first it was thought that it might be possible to repair the fiberglass balsa wood structure; however, this turned out not to be possible. Hans Kautzky took an all-metal CERN back-up piston design and modified it for use in the 15 Foot. He was able to rush through the parts and supervised the extensive welding job and we were able to use this back-up piston for the initial runs. This was a very important step in being able to start the experiments.

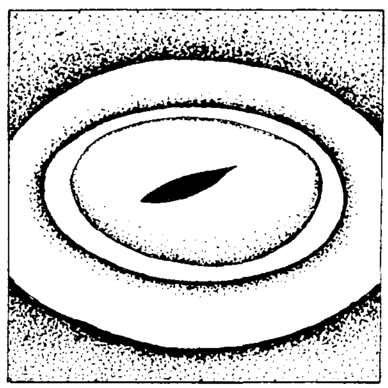
Safety considerations were always in the forefront of 15 Foot efforts. Paul Hernandez from LBL, the chief engineer on the first large hydrogen bubble chamber (LBL's 72-in.), joined the 15 Foot as Bob Wilson's 15 Foot Bubble Chamber safety officer. He organized a safety committee and carried out numerous reviews. The safety procedures were highly documented and Elsie Renaud and Paul, along with Russ Huson, can testify as to the large effort that went into this activity.

I might close with some comments on the early days of the 15 Foot Bubble Chamber. After the effort was started in January 1970, Elsie Renaud came to NAL and was the administrative secretary for many years. Russ Huson joined the effort almost immediately, moving from the Shutt group at BNL. George Mulholland was one of the early recruits and he, from the beginning, was designated to take over the operations including commissioning. We also benefited from many people who transferred from the 12-ft. chamber at ANL. It was an exciting, dynamic period appropriately remembered on the occasion of the retirement of the 15 Foot Bubble Chamber.

Edwin Goldwasser
University of Illinois, Urbana-Champaign

I have long since found that my memory, if anything at all, can play strange tricks on me. I have tried to think back to the beginnings of the 15 Foot Bubble Chamber but without great success. Then, more recently, I have been aided by having a set of transcriptions of the talks that were given at the 15 Foot Fest that I was unable to attend. Those talks served to refresh my memory--or at least to reconstruct it--but they also served to indicate that everything that I could possibly remember had already been remembered and said by someone else. In desperation, then, I have dreamt up one additional thought.

I do remember that way back in 1967 neither Bob Wilson nor I were convinced that the bubble chamber, in spite of its fantastic past and recent contributions, was likely to be a competitive detector for exploring the physics of the next generation. My own most recent research had been done with a bubble chamber, and so I was seen as a natural "godfather" and defender of the bubble chamber's fate for the Fermilab future. In fact, it took a good deal of soul searching before I decided that I could in good conscience (and should, given my responsibilities), make the case for including a large bubble chamber within the coterie of facilities with which Fermilab might strike forth into virgin territory. The reasons, frankly, were not primarily any of the unique characteristics or capabilities of bubble chambers, large or small. My reasons had more to do with my conviction that all the intellectual power of the particle physics community would be badly needed in order to wrestle with the new physics, the complex events and the overwhelming backgrounds that would characterize the new high-energy frontier at Fermilab. I'll have to say somewhat gratuitously, that I still remembered both the outstanding successes and the outstanding excesses of a man whose work and ingenuity we all sincerely admired--Luis Alvarez. Among the successes was the development of a man-sized hydrogen bubble chamber and of the analysis techniques and facilities that were necessary to handle the new quantities of data that came from randomly expanded bubble chamber photographs. But Luis' success also led to one unfortunate excess. In the 1970's he wrote a letter to agencies sponsoring high-energy physics advising them that all experiments in particle physics could best be accomplished

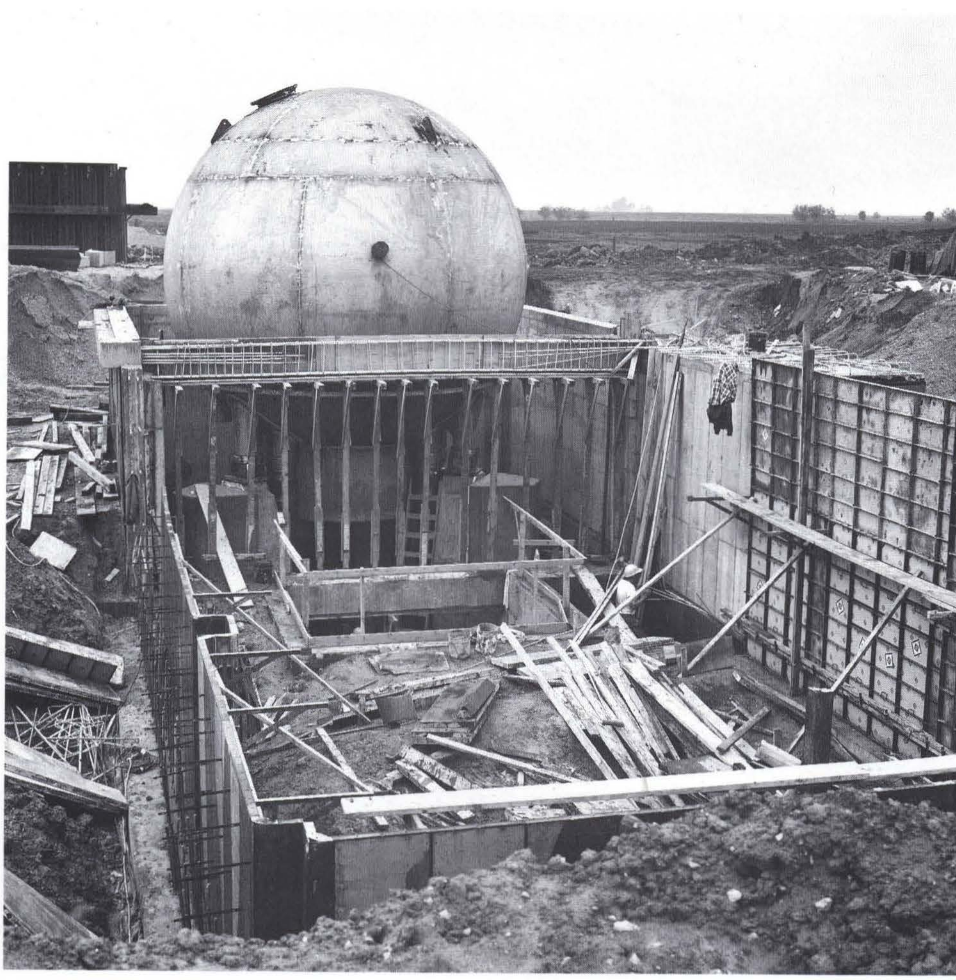


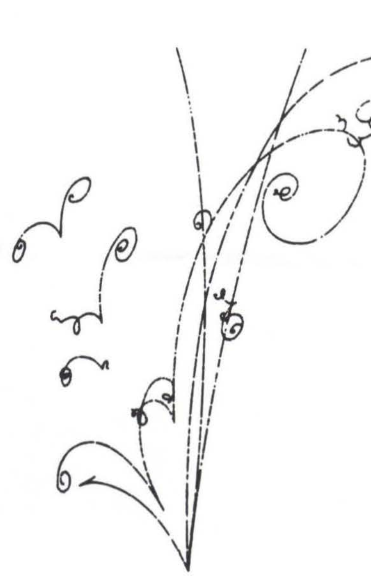
through the use of hydrogen bubble chambers. He further admonished them to reduce toward zero their support of experiments involving electronic detecting and counting devices. That excess of Luis' had an influence on me. I was so convinced that he would be proven to be wrong about the exclusive superiority of bubble chamber detectors that I was somewhat inclined to demonstrate my own incredulity by ignoring the bubble chamber as an interesting instrument for Fermilab experiments. In the long run, I was able to overcome my prejudice and to work hard toward the construction of the 15 Foot Bubble Chamber and toward the implementation of a bubble chamber program at Fermilab.

The principal rationalization for that decision had to do, as I have suggested earlier, with the rather large core of physicists who had been engaged in bubble chamber physics and who wished to embark on Fermilab physics using their familiar bubble chamber techniques. As I reminisce today, I have no hard facts or numbers in hand. That makes it all the easier to make categorical statements that may or may not be entirely true. My strong feeling, nevertheless, is that there were several hundred bubble chamber users in the high-energy physics community and that they could only be involved in the Fermilab physics program through the construction and operation of a substantial bubble chamber that would provide them with the kind of particle physics data that they were used to handling. It was thus only through the implementation of a bubble chamber program that the intellectual resources of this large segment of the high-energy physics experimental community could be retained and brought to bear on the physics of Fermilab.

Neglecting all of the other statements that have been made concerning the productivity of the 15 Foot Bubble Chamber, in my judgment, on the grounds of scientific involvement alone, the 15 Foot Bubble Chamber paid off substantially on the investment that had to be made to bring it into being. It goes without saying that as physics changed in the new higher-energy region and as detector technology developed in response to the demands of the new physics, many of the physicists who were brought into the research program at Fermilab only by involvement in the 15 Foot Bubble Chamber program later went on to branch out into the use of other non-bubble chamber related techniques. Again, without confusing facts at hand, it is my guess that the experimental program of the Mark II detector at SLAC, the Time Projection Chamber (TPC) at SLAC, the CDF Detector at Fermilab, and the developing DO Detector at Fermilab all benefited from contributions which eventually rose from the bubble chamber segment of the high-energy physics community and was attributable to maintaining active interests and involvement in experimental particle physics *only* through the advent of the Bubble Chamber program at Fermilab.

With that observation, I join all of the others in expressing my thanks and admiration to all of those who labored hard and imaginatively, initially to bring a plan for a 25-ft. bubble chamber to fruition, but later to bring the reality of a 15 Foot Bubble Chamber into being and for establishing an enviable record of safety and operational effectiveness for a very complicated facility that was a new pioneer in its range of size and magnetic field intensity.





2012 Received film developed at ANL of chamber full of hydrogen. All three views are unif[orm] light compared to the earlier warm pictu[res] Judging from earlier test strips we need to increase the joules to 120% of their earlier values

port	old flash voltage	new flash voltage	
1	1550 Volts	1700 Volts	set i[n] 2200
2	1700	1850	
3	1750	1900	

we should take about 400 pictures on each camera at the new flash voltages of the chamber full with very stable tempe[rature] conditions in the ~~chamber~~ hydrogen. This film should be developed at ANL. W

2028 USED SAME REF VOLTAGE (.15V) FOR REF, Z SECTION LI 446. NOW IT SHOWS FULL ALSO!

Z SECTION FULL TOO. TOO MUCH SO

1. WILL BLEED OUT TO SHIS LEVEL,
2. AND START PRESSURE COOLING LOOPS,
3. CONTROL CH. PRESS - TEMP.
4. TAKE PICTURES.

2400 Cycled PV-105 to open & close - Bleeding off the "Z" section which appears to be over-filled.

Wesley Smart

Fermilab

I first really came to the notice of Bill Fowler, then group leader, during the first cooldown of the 15 Foot Bubble Chamber in the summer of 1973. I was in the control room a lot and discovered that, by lighting my pipe directly below an overhead smoke detector, I could set it off. The resulting alarm would bring the firemen, then located in the old firehouse in the Village, to the 15 Foot Bubble Chamber in a few minutes, followed a couple of minutes later by a dripping-wet group leader who had been at the swimming pool along the fireman's route. While Bill was relieved to find that nothing more serious than a pipe being lit in the control room was occurring at the Bubble Chamber, I think he was getting a little tired of making the trip after the third time. I did learn, after that, to walk to the far side of the control room before lighting up.

I was working for the Accelerator Division during 1976-78, but even then I was an experimenter on the 15 Foot Bubble Chamber runs as well as a member of the safety committee. Since I returned as a group leader in 1978, I believe I may have set some kind of a Fermilab record by having seven different bosses in 9.5 years, while keeping the same job through two reorganizations. I do feel that I got along well with all seven and that they all had a real respect for the difficult job that the operating crew was doing at the chamber.

My relationship with the spokespersons of the experiments running at the 15 Foot Bubble Chamber has been more mixed. Someone always had a good word for us, even when things were going badly, while others always found something to complain about, even when things were going well. Most had a real respect for the job we were doing in operating the chamber; others thought they could run things better themselves and rarely missed an opportunity to let us (and our bosses) know it, and even frequently tried to randomly micro-manage details of the operation. At one point, our Safety Committee cautioned "Safety at the 15 Foot Bubble Chamber requires the 15 Foot Bubble Chamber staff... be adequately buffered from user demands."

I believe we always had a good relationship with our Safety Committee, partly because many of its members had extensive experience building and operating bubble chambers. I would like to thank them, especially the chairman, Paul Hernandez, for their many years of cooperative and helpful service.

Even our excellent Safety Committee could do little about the worst hazard facing our crew: After almost every game of the 15 Foot Bubble Chamber Softball Team there would be two or three "walking wounded" with splints on their fingers, and frequently someone hobbling around on crutches for weeks.

I would like to thank Leon Lederman and Ken Stanfield for strongly supporting the Bubble Chamber, especially holography, during this last run, even though what they really wanted to do was shut us down. I actually believe the main reason operations have now ended is the basic mismatch between the requirements of neutrino physics in the 15 Foot Bubble Chamber and the parameters of the Tevatron, especially considering the needs of other experiments. The 400 GeV accelerator could send up to $2x10^{13}$ protons to the neutrino target as often as every six seconds, while the Tevatron could only spare about $0.5x10^{13}$ protons per minute, divided among three neutrino beam pulses. While the neutrinos from the higher energy protons produced more events per proton, this didn't make up for longer cycle time and fewer protons.

Over the years, many other Fermilab groups, too numerous to mention, contributed to the successful operation of the chamber. One noteworthy event occurred during our preparations for this last run; we had more manpower sent to help us from the rest of the Cryogenics Department than we had loaned out to other Fermilab groups. During the last eight years this balance had consistently been in the other direction.

The main credit for the successful operation of the 15 Foot Bubble Chamber since 1973 goes to the many people on the crew over these 15 years. I would like to add my thanks to all these people for their fine work, with special thanks to those who stayed to the end to help make this last run so successful. I am proud that the chamber finished the run in good operating condition and took a picture of the last pulse of beam sent to it.

Finally, I would like to thank Jim Kilmer for an extremely successful, constructive, and pleasant partnership in running the 15 Foot Bubble Chamber for the last eight years.


BLOCK
ALL
CARTS
PERSONNEL
MUST NOT
RIDE THE
ELEVATOR

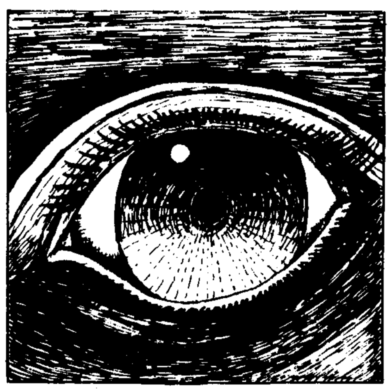
Robert R. Wilson

Cornell University

We had many exciting adventures in the course of building Fermilab. One of these involved the construction and use of the 15 Foot Bubble Chamber, and now, as it reaches retirement, we can review that construction and use, we can celebrate its accomplishments, we can sentimentalize, perhaps we may even learn something of value for future projects of this kind. My recollections will be confined to how we came to build the 15 Foot Bubble Chamber.

Now, the Berkeley Design Report for the 200-BeV Proton Accelerator had included some $60 million which, among other things, envisioned one 2m^3, one 100m^3, and one large borrowed bubble chamber. When the scope of the project was drastically reduced, these were all thrown out of the authorization plan along with the reduction of machine intensity and the scope of the experimental areas. Of course, the elimination of the funding for the bubble chambers did not eliminate the need for them.

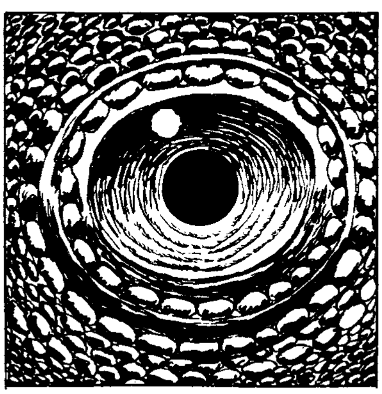
I can't say that I was an aficionado of bubble chambers, quite to the contrary. Still, I had been deeply impressed by what the Alvarez group at Berkeley had accomplished, and bubble chambers did seem to be the ideal instrument for a preliminary investigation of the new energy range we would be exploring at Fermilab. More importantly, the experimenters who would use the accelerator made it very clear that a large bubble chamber should be one of the necessary facilities of the project. When the first Aspen summer study in 1968 had finished, there had been a general agreement that a 25-ft. bubble chamber would be required to do the job. The Brookhaven National Laboratory (BNL) physicists volunteered to design it along the lines of the 7-ft. bubble chamber which was just moving into the last stages of construction at BNL. Their efforts resulted in an elegant design (The 25-ft. bubble chamber, October 1969). Alas, the proposal was turned down with a finality that precluded any future appeal. Perhaps the Atomic Energy Commission (AEC) was so obdurate because its volume was more than twice that envisaged in the Berkeley Study or perhaps it was because the estimated cost of the chamber ($15 million), seemed then to be so terribly high. At that point I decided that we could somehow squeeze the chamber out of our dwindling construction costs, and so we,



and by we I mean Ned Goldwasser and other physicists working on the experimental facilities, asked the bubble chamber advocates to come up with a more modest, but yet still adequate, design. Just then a "Fairy Godmother" in the form of Bill Wallenmeyer of the AEC appeared, waved a magic wand, and pried out new funds, from whence I never did understand. That Brookhaven National Laboratory made the design, that the Argonne National Laboratory would build the huge superconducting magnet, and that the Stanford Linear Accelerator Center would build the piston were also vital ingredients in moving forward with the project.

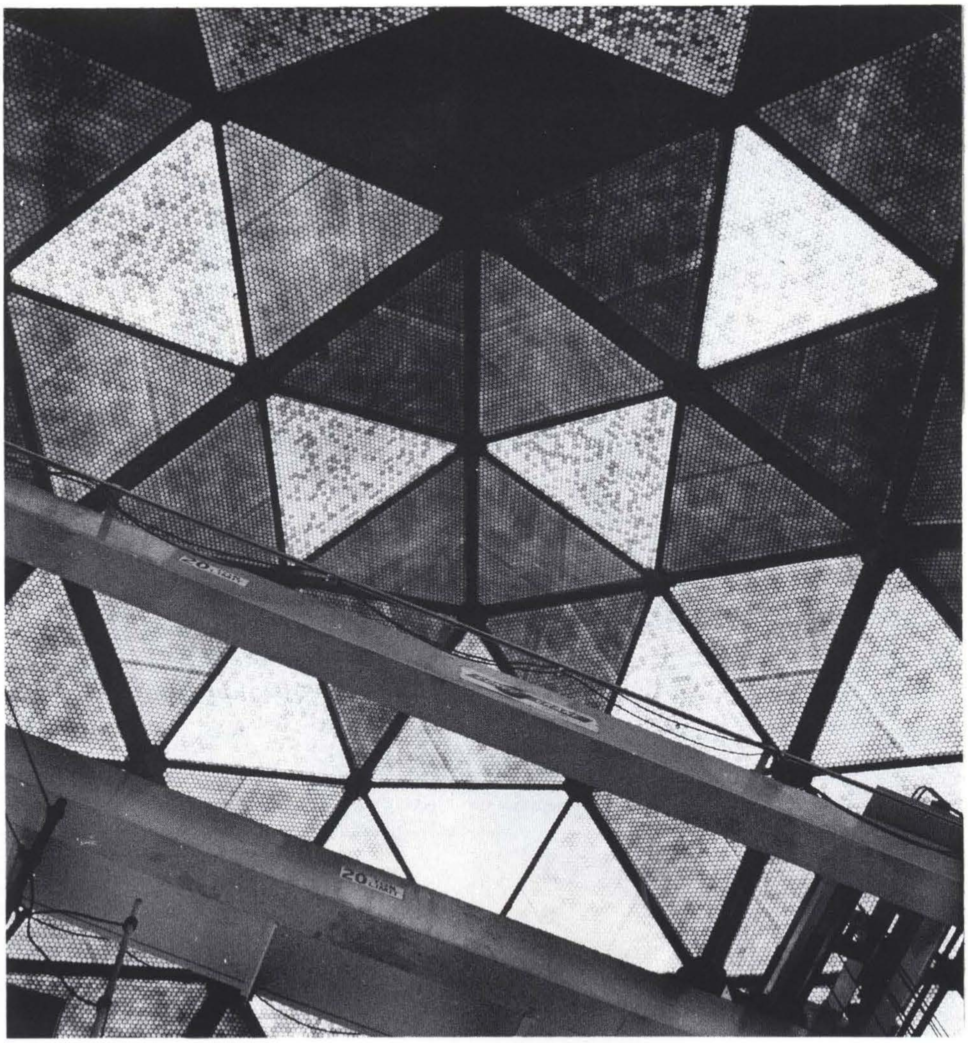
The new funds were, as I remember, about $7 million. In the contriving that went on determining just how much they should be, I had made an obligation that it be a 15 Foot Bubble Chamber. Somehow in the rush to a new design, which meant essentially just doubling the 7-ft. BNL design, the diameter was reduced to 14 feet. I insisted, for no other reason than my own credibility, that we stick to 15. So as not to have to make a whole new design, it occurred to me that a small one-foot-long conical extension on the front of the chamber would keep me honest, and might even find some use in extending the length of the damn thing. I learned somewhat later that there were some comedians who referred to it, with egregious *les majeste*, as the "Wilson Nose."

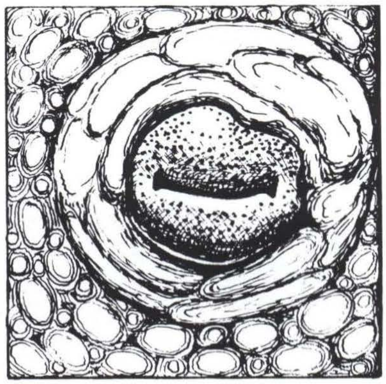
Soon after, Bill Fowler joined the Laboratory to see the project through - a great day for Fermilab. Not much later Russ Huson joined him. I always felt that the sophistication of the engineering on the 15 Foot Bubble Chamber far exceeded what we were doing on the accelerator. It was a delight for me, every now and then, to pause in our mad race to admire the bravura performance of our clever new friends.



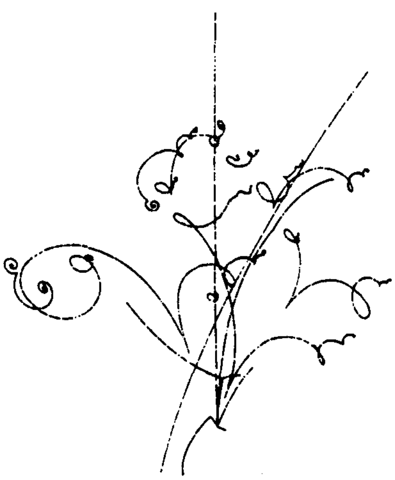
One of the fantasies that I had acquired during the lengthy discussions about the chamber was that it would sit out on the lone prairie in its shiny spherical magnificence about a mile from the Central Laboratory Building. In this case, architecture would not only reflect the function, it would *be* the function, or visa versa. It finally became evident to me that the topography was such that the top of the chamber might just about stick up above ground, if that, and that the miserable neutrino berm would conceal everything anyway. I was so angry that I didn't know whether to cancel the neutrino experiments or the 15 Foot Bubble Chamber itself!

The resolute Fowler and Huson were not to be deterred by my architectural whimsey. They came to me with wily smiles - they would fight fire with fire. The 15 Foot Bubble Chamber would need an assembly building, they informed me. Aha, more money yet, I thought to myself. The new building, which would also be the operational center, would sit next to the bubble chamber, and it would have a huge bubble, indeed, a Fuller dome, sitting on top of it as a necessary part of it. That got to me. Soon my anger dissipated as we busily started the design. In fact Russ already had a design in his pocket, and I even forgave him for that in the general euphoria of the moment.





When we turned our thoughts over to the professional architects of DUSAF, our architect/engineer consortium, they informed us that Fuller buildings had become expensive - way beyond what I was willing to spend. Still the idea of a domed structure was irresistible, so we cut a deal with DUSAF that they would design and build the bottom floor of the building and we would take responsibility for the dome. Everybody seemed to get into the act, but Bob Sheldon, an innovative chemist working in the coil factory at West Chicago, came up with a brilliant idea for a new kind of sandwich board that promised to be strong, cheap, and beautiful. It was to consist of two plastic layers between which beer cans would be stacked side by side in a hexagonal array and then cemented into place. Instead of a dome I chose an icosahedron shape which I thought would look like a jewel sitting on top of the rectangular base building, but with its five sides it was something of a problem. Hank Hinterberger, our chief engineer, designed a steel structure to support the facets of the icosahedronic dome. The plates were triangles nine feet on each side and were made in our coil factory. The thin plastic layers were translucent and of different colors. The beer cans were collected from the parking area of the factory by a local Boy Scout Troop - our first community project. The tops and bottoms of the cans were removed so that when assembled the translucent plastic plates took on the appearance of stained glass. The building was thoroughly satisfactory, even though the plastic decomposed in the sunlight over the years and has now been replaced by copper panels.



Well, I am getting deeper and deeper into superficialities which have little to do with the substance of the 15 Foot Bubble Chamber, which is being addressed in the other contributions to this volume. Quite apart from the Bubble Chamber itself, building it brought a technical sophistication to Fermilab that was to permeate the whole Lab, and was eventually even to make the superconducting Tevatron a realizable possibility. Memories, pleasant memories.

The Village Crier

fermi national accelerator laboratory

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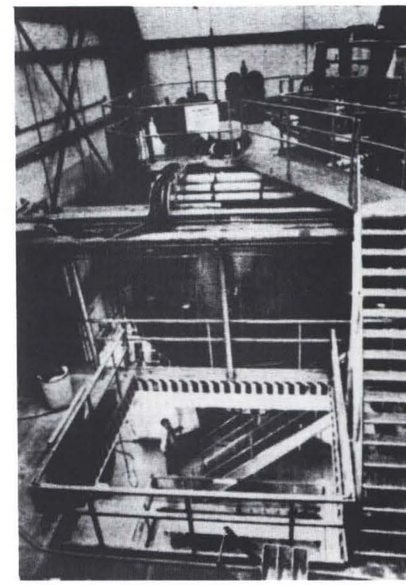
May 15, 1975

15-FOOT CHAMBER COMPLETES HISTORIC RUN



...Fermilab's 15-Foot Bubble Chamber...

The 15-foot Bubble Chamber at Fermilab recently completed a history-making run which saw both a new phase of bubble chamber operation and a new phase of experimenting at Fermilab.

The Fermilab 15-foot Chamber was commissioned in September, 1973. It contains a large stainless steel sphere, which is filled with clear cryogenic liquid in which a beam of particles coming from the accelerator can interact. The particles are momentun-resolved by a 30,000 Gauss superconducting magnet surrounding the chamber, while four cameras overhead snap photographs on each pulse of the accelerator. The photos of the interactions of the particles within the liquid of the chamber give precise, tangible evidence of these interactions. Bubble Chambers have become one of the most important sources of knowledge about the phenomena that occur in particle physics.

In the recent run at Fermilab the chamber was filled with a mixture of 80% liquid hydrogen and 20% liquid neon. Because neon weighs seventeen times more than hydrogen (the liquid used in previous runs) a formidable operating challenge confronted the crews from the outset. Operating with this neon-hydrogen mixture necessitated precise testing of the temperature controls and mechanical properties of this relatively new chamber.

Once again, the crews whose skill and spirit have already become well-known at Fermilab as they have brought this unique piece of equipment to life in the past eighteen months, went into action. Only once before in high energy physics has a large chamber operated with neon, although it is used commonly in small bubble chambers.

Filling of the chamber with liquid neon required careful mixing so that the physics results could be accurately computed. Because of its density, the neon increases the neutrino interaction rate by a factor of four. More than a year of careful scheduling was necessary to accumulate and process the amount of crude (75% Ne/25% He) neon needed to fill the chamber; the liquifying of 10,000 liters took five days before the run. A valuable commodity, worth $10 per liter, the neon is recognized as an investment and may be loaned to other laboratories after its current use at Fermilab.

With the chamber filled, operation began, and in a matter of hours photographs could be taken. Hans Kautzky, one of the leaders of the 15-foot group, observes, "Once the chamber is filled and begins operation it can not be switched off like most other beam equipment but, more like a new-born shark, it must keep going and never stop until the end."

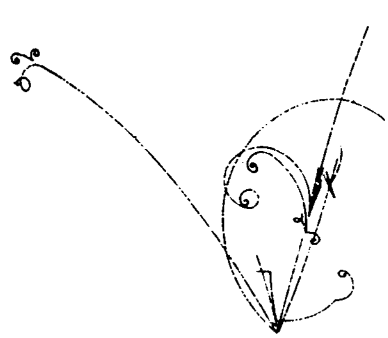
The operational success is measured by the experimental results. Experiment #28, a collaboration between physicists from the University of Wisconsin, the University of Hawaii, Lawrence Berkeley Laboratory, and CERN, studied neutrino interactions on this run of the chamber. The chamber was teamed with the Hawaii-LBL external muon identifier, a wire

do not look for it ⟶ (Continued on Page 2)

Appendices
Appendix A
Approved Experiments which ran with the 15 Foot Bubble Chamber with Publications

This appendix contains a description of all experiments that were approved and ran with the 15 Foot Bubble Chamber. A brief history of each experiment is given which contains the record of the experiment's spokesperson, beamline, collaborators, physics goals, requests, approvals, completion date, and all publications known to have come from the experiment up to the time of the printing of this book. Much of the information that is compiled in this section can be found in the *Fermilab Research Program Workbook 1987* edited by Roy Rubinstein and published by the Program Planning Office at Fermilab.

One word of explanation. A number of times throughout the course of the 15 Foot presentations, speakers referred to the total number of experiments performed *with* the 15 Foot Bubble Chamber as 17. It should be noted that this number neglects 2 experiments that were not done *with* the 15 Foot Bubble *Chamber*, but were done *on* the 15 Foot Bubble Chamber *with* the 15 Foot Bubble Chamber *Magnet*. These 2 experiments, E-202 and E-502 were run parasitically, using the 15 Foot Bubble Chamber Magnet's field and cosmic rays that were incident on an apparatus which was mounted on top of the chamber.



1) **Experiment E-28A** (Neutrino/H2&NE)

Spokesman: William F. Fry

Beamline: Wide Band Horn Neutrino Beam

Institutions

CERN
Hawaii, University of
Lawrence Berkeley Laboratory
Wisconsin, University of Madison

Physics Goals

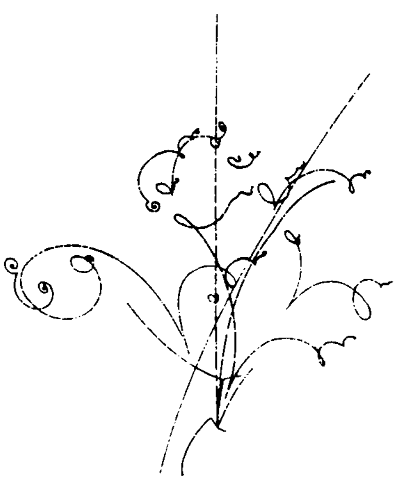
E-28A was a search for heavy leptons and hard penetrating radiation in the neutrino beam. It included a study of diffraction scattering of neutrinos, a study of deep inelastic muon-neutrino scattering in a hydrogen-neon bubble chamber, and tests of the Delta S = Delta Q rule at high momentum transfer using inclusive reactions.

Request

E-28A requested 1,000K pictures on June 15, 1970, of which 500K were to be taken with the primary protons incident on the hadron shield and 500K were to be taken with normal targetry.

Approval

E-28A was approved to run on December 1, 1971, with 100K pictures, 50K of which were of neutrinos in neon (greater than or equal to 30%) with the constraint that running conditions yield at least 10,000 events. The other 50K pictures would be of neutrinos, using special targeting of neutrinos in the 22% neon mixture under Horn focusing.



Completion

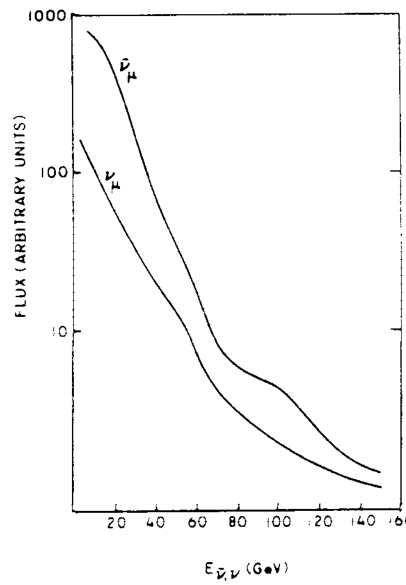
E-28A was completed on June 11, 1975 with a total of 97K pictures taken.

Publications

Observation of $\mu^- e^+ K_s^0$ Events Produced by a Neutrino Beam. Phys. Rev. Lett. **36**, 710 (1976).

K^0 Phenomena Associated with Neutrino-Induced $\mu^- e^+$ Events. Phys. Rev. Lett. **38**, 1248 (1977).
A Study of the Reaction $\nu_\mu N \rightarrow \mu^- e^+ + X$. Nucl. Phys. G **3**, 1 (1977).

2) Experiment E-31A (Anti-Neutrino/H2)



Spokesman: Malcolm Derrick
Beamline: Wide Band Horn Neutrino Beam

Institutions

Argonne National laboratory
Carnegie-Mellon University
Purdue University

Physics Goals

E-31A's proposal was to investigate muon-antineutrino interactions in hydrogen.

Request

On June 15, 1970, E-31A requested 1,000K pictures which required a total exposure of 10^{19} protons with 10^{13} protons per pulse incident on target.

Approval

The experiment was approved on December 1, 1971 and allocated 200K pictures with a further constraint that the overall running conditions yield at least 7,000 antineutrino interactions.

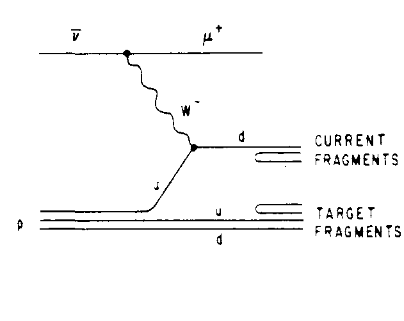
Completion

E-31A was completed on August 13, 1977 and accumulated a total data sample of 211K pictures.

Publications

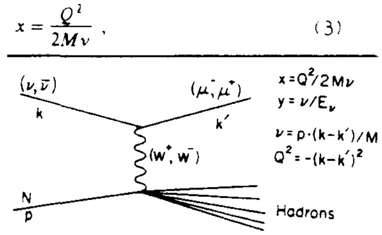
Study of High-Energy Antineutrino-Proton Interactions. Phys. Rev. Lett. **36**, 936 (1976).

Neutrino and Antineutrino Proton Scattering Data and the Ratio of Down to Up Quarks in the Proton. Phys. Lett. B **69**, 112 (1977).



Properties of the Hadronic System Resulting from $\overline{\nu}_\mu p$ Interactions. Phys. Rev. D **17**, 1 (1978).

Strength of the Antineutrino-Proton Neutral-Current Interaction. Phys. Rev. D **18**, 7 (1978).



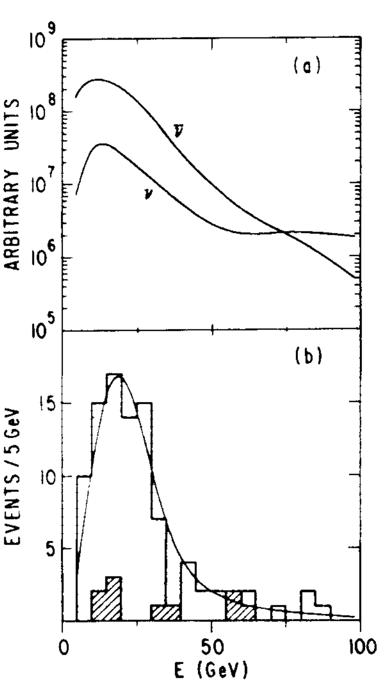
Scaling-Variable Distributions in Deep-Inelastic Antineutrino-Proton Interactions. Phys. Rev. D **18**, 2205 (1978).

x Dependence of the Proton Structure Functions from Inelastic Antineutrino-Proton Scattering. Phys. Rev. Lett. **43**, 1975 (1979).

Comparison of Jet Size in $\bar{\nu}p$ Interactions with that in e^+e^- Annihilation. Phys. Lett. B **88**, 177 (1979).

Study of Charmed-Quark Production by Antineutrinos. Phys. Rev. Lett. **45**, 783 (1980).

Study of the Reaction $\bar{\nu}p \to \mu^+ p \pi^-$. Phys. Lett. B **91**, 161 (1980).



Inclusive ρ^0 Production in $\bar{\nu}p$ Charged-Current Interactions. Phys. Lett. B **91**, 307 (1980).

A Test of Quark Fragmentation in the Quark-Parton Model Framework. Phys. Lett. B **91**, 470 (1980).

Hadron-Production Mechanisms in Antineutrino-Proton Charged-Current Interactions. Phys. Rev. D **24**, 1071 (1981).

Measurement of Quark Momentum Distributions in the Proton Using an Antineutrino Probe. Phys. Rev. D **25**, 1 (1982).

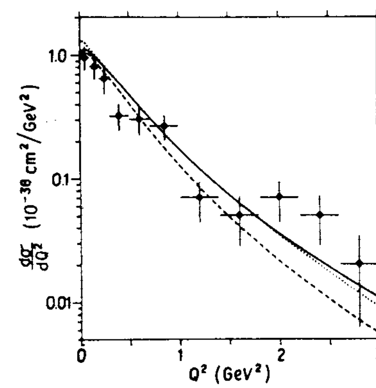
Multiplicity Distributions in $\bar{\nu}_\mu p$ Interactions. Phys. Rev. D **25**, 624 (1982).

Strange-Particle Production in High-Energy $\bar{\nu}$ and ν Charged-Current Interaction on Protons. Phys. Rev. D **25**, 1753 (1982).

Measurement of the Neutral-Current-to-Charged-Current Cross-Section Ratio for Antineutrino-Proton Inclusive Scattering. Phys. Rev. D **26**, 2965 (1982).

3) Experiment E-45A (Neutrino/H2)

Spokesman: Frank A. Nezrick
Beamline: Wide Band Horn Neutrino Beam



Institutions

Fermi National Accelerator Laboratory
Hawaii, University of
Lawrence Berkeley Laboratory
Michigan, University of

Physics Goals

E-45A was a proposal to study neutrino interactions with protons.

Request

E-45A requested 200K pictures on June 15, 1970 with 10^{13} protons per pulse incident on the primary production target with an energy of 200 GeV. On July 19, 1970 they subsequently requested 500K pictures with 10^{13} protons per pulse incident on the primary production target with an energy of 350 GeV.

Approval

The experiment was approved on December 17, 1971 and allocated 300K pictures maximum with the constraint that the running conditions yield on the order of 15,000 events of neutrinos in hydrogen.

Completion

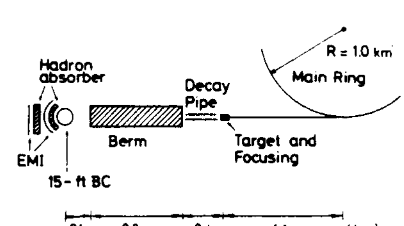
E-45A was completed on January 13, 1976, having accumulated 162K pictures.

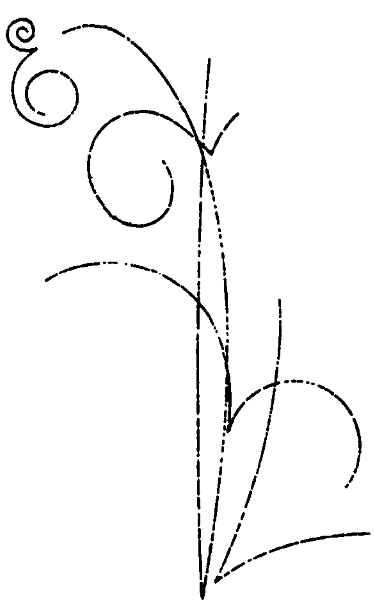
Publications

Multiplicity Distributions in High-Energy Neutrino Interactions. Phys. Rev. Lett. **36**, 124, (1976).

Experimental Study of Inclusive Deep Inelastic Neutrino-Proton Scattering. Phys. Rev. Lett. **36**, 639 (1976).

Inclusive Strange-Particle Production by *vp* Interactions in the 10-200-GeV Region. Phys. Rev. Lett. **36**, 127 (1976).





Neutrino-Proton Interactions at Fermilab Energies: Experimental Arrangement, Analysis Procedures, and Qualitative Features of the Data. Phys. Rev. D **14**, 5 (1976).

Ratio of Neutral-Current to Charged-Current Cross Sections for Inclusive Neutrino Interactions in Hydrogen. Phys. Rev. Lett. **39**, 437 (1977).

Comparison of Scaling Deviations in Neutrino, Electron and Muon Inelastic Scattering. Phys. Lett. B **67**, 347 (1977).

Diffractive Production of Vector Mesons in High-Energy Neutrino Interactions. Phys. Rev. Lett. **40**, 1226 (1978).

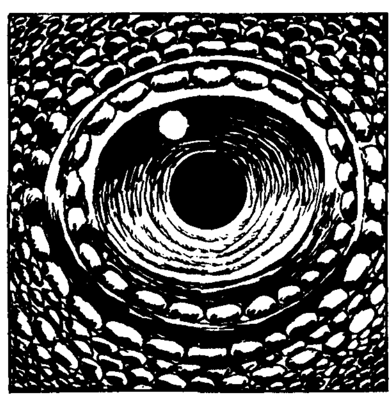
Cross-Section Measurements for the Reaction $\nu p \to \mu^- \pi^+ p$ and $\nu p \to \mu^- K^+ p$ at High Energies. Phys. Rev. Lett. **41**, 1008 (1978).

Study of Reactions $\nu p \to \mu^- \Delta^{++}$ at High Energies and Comparisons with Theory. Phys. Rev. Lett. **41**, 1012 (1978).

Inclusive Neutral-Strange-Particle Production from High-Energy νp Charged-Current Interactions. Phys. Rev. D **18**, 1359 (1978).

Experimental Study of Hadrons Produced in High-Energy Charged-Current Neutrino-Proton Interactions. Phys. Rev. D **19**, 1 (1979).

Inclusive Production of Nonstrange Resonances in High-Energy νp Charged-Current Interactions. Phys. Rev. D **22**, 1043 (1980).



4) Experiment E-53A (Neutrino/H2&NE)

Spokesman: Charles Baltay
Beamline: Wide Band Horn Neutrino Beam

Institutions

Brookhaven National Laboratory
Columbia University

Physics Goals

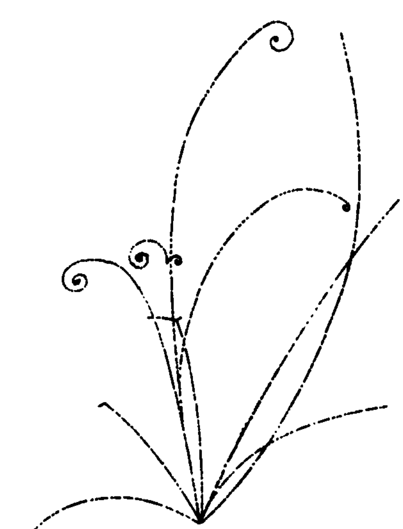
This experiment was a search for the intermediate vector boson, lepton pair production, and also involved a study of deeply inelastic reactions utilizing high-energy neutrino interactions in liquid neon.

Request

Experiment E-53A made a series of requests based on the results of a continuing and productive physics program. Their first request was made on June 15, 1970 when they asked for 1,000K pictures of neutrino interactions with 70% neon and 30% deuterium and plates inserted into the chamber. This was followed by a request for 1,000K pictures on July 6, 1971, specifying that 900K of the pictures be of neutrino interactions in neon using a single plate and the remaining 100K pictures be taken in hydrogen with 2 plates. The experiment later requested 200K pictures on June 16, 1976 which was a request for an increase in the approved picture total from 100K to 200K. On January 25, 1978 the experiment requested 450K pictures which were to include an increase of 300K beyond the approximately 150K pictures presently available for the experiment. In addition, at least 150K more pictures were requested during the Summer or Fall of 1978. Their final request was submitted on June 19, 1978 for 450K pictures which would include an increase of 300K pictures.

Approval

The first of a number of approvals for E-53A was given on December 17, 1971 when they were allotted 100K pictures in neon-hydrogen or with the plates inserted into the chamber to yield at least 20,000 events. The second approval came on June 29, 1976 when the experiment was allotted 150K pictures total, including about 50K pictures that had already been taken earlier. The final approved occurred on June 28, 1978 with an allocation of 450K pictures total, including an extension that was granted to the experiment for 300K pictures.



Completion

The experiment was fully completed on March 9, 1981 and had accumulated a total data sample of 440K pictures.

Publications

Dilepton Production by Neutrinos in Neon. Phys. Rev. Lett. **39**, 62 (1977).

Experimental Limits on Heavy Lepton Production by Neutrinos. Phys. Rev. Lett. **40**, 144 (1978).

Charmed-D-Meson Production by Neutrinos. Phys. Rev. Lett. **41**, 73 (1978).

Measurement of the Cross Section for the Process $\nu_\mu + e^- \rightarrow \nu_\mu + e^-$ at High Energies. Phys. Rev. Lett. **41**, 357 (1978).

Confirmation of the Existence of the Σ_c^{++} and Λ_c^+ Charmed Baryons and Observations of the Decay $\Lambda_c^+ \rightarrow \Lambda\pi^+$ and $\overline{K}^0 p$. Phys. Rev. Lett. **42**, 1721, (1979).

Experimental Limits on Neutrino Oscillations. Phys. Rev. Lett. **47**, 1576 (1981).

Limits on Like-Sign Dilepton Production in ν_μ Interactions. Phys. Rev. Lett. **55**, 2543 (1985).

Opposite-Sign Dilepton Production in ν_μ Interactions. Phys. Rev. D **32**, 531 (1985).

Evidence for Coherent Neutral-Pion Production by High-Energy Neutrinos. Phys. Rev. Lett. **57**, 2629 (1986).

Strange-Particle Production in Neutrino-Neon Charged-Current Interactions. Phys. Rev. D **34**, 1251 (1986).

5) Experiment E-155 (External Muon Identifier Test)

Spokesman: Vincent Peterson
Beamline: Wide Band Horn Neutrino Beam

Institutions

Hawaii, University of
Lawrence Berkeley Laboratory

Physics Goals

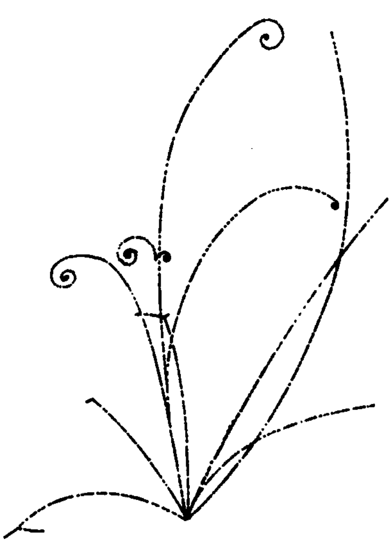
E-155's proposal for a test run involved developing a phase I External Muon Identifier (EMI) to be used with the 15 Foot Bubble Chamber. This apparatus would enhance the operation of the 15 Foot and overcome limitations set by the fiducial volume of the chamber.

Request

The formal request was registered on July 15, 1971.

Approval

The experiment was given three separate approvals to run, with the first two being parasitic test runs. The first parasitic run was approved on August 27, 1971 with the understanding that completion of Phase I of the EMI will include tests in the neutrino beam with the 15 Foot Bubble Chamber in operation and that the number of pictures to be allotted to the experiment would be decided at a later date. The second parasitic run was approved on December 17, 1971 with 100K pictures to be taken from experiment E-45A's exposures which would be taken when the EMI was operating. The film containing about 200 events to be delivered as soon as feasible to aid in the preliminary tune up and checking out of the apparatus. The final approval for 50K pictures came on June 26, 1974, with the formal approval for dedicated pictures for E-155 to follow the successful analysis of 200 events from the E-45A exposures.



Completion

The experiment was completed on November 30, 1974 and had accumulated a total of 14K pictures.

6) **Experiment E-172** (Anti-Neutrino/H2&NE)

Spokesman: Henry J. Lubatti
Beamline: Wide Band Horn Neutrino Beam

Institutions

California, University of, Berkeley
Hawaii, University of
Lawrence Berkeley Laboratory
Washington, University of

Physics Goals

This experiment was interested in studying antineutrino interactions in hydrogen/neon.

Request

Formal request was made on May 16, 1972 with the number of pictures requested at 50K.

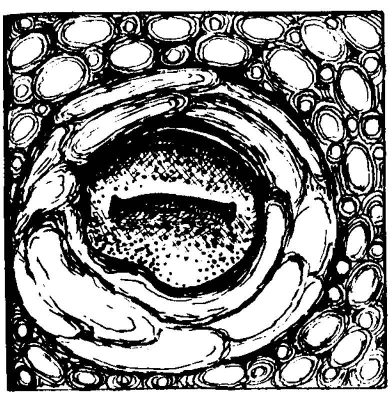
Approval

E-172 was approved on July 19, 1972 with the total allotment of pictures being 50K.

Completion

The experiment was completed on May 25, 1976, having accumulated a total data sample of 49K pictures.

Publications



Observation of μe Events in $\bar{\nu}$ and ν Interactions in Neon. Phys. Rev. Lett. **39**, 1650 (1977).

Hadron Production in νNe and $\bar{\nu}$Ne Interactions. Phys. Lett. B **77**, 443 (1978).

Comparison of Electron and Muon Charged Current Neutrino and Antineutrino Interactions in a Neon-H_2 Mixture. Phys. Lett. B **79**, 320 (1978).

Multiplicity of Charged Particles in π^- Neon Interactions at 25 and 50 GeV/*c*. Acta Phys. Polon. B **9**, 513 (1978).

7) Experiment E-180 (Anti-Neutrino/H2&NE)

Spokesman: Pavel F. Ermolov
Beamline: Wide Band Horn Neutrino Beam

Institutions

Fermi National Accelerator Laboratory
Institute of Theoretical & Experimental Physics, Moscow (USSR)
Institute of High Energy Physics, Serpukhov (USSR)
Michigan, University of

Physics Goals

The experiment proposed a study of antineutrino interactions in hydrogen and neon.

Request

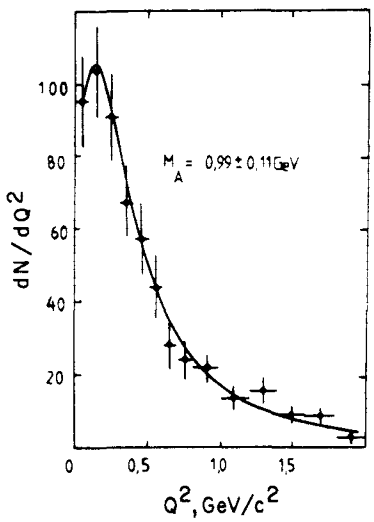
The request was made on June 23, 1972 for a data sample of 200K pictures.

Approval

The experiment was approved on July 11, 1972, being allotted 50K pictures of antineutrinos and further that they would run before experiment E-172 and and have the first choice of the two hydrogen/neon mixtures. The experiment was approved to run a second time on June 29, 1976 for 200K pictures which included an additional 150K pictures with the expectation that the experiment will involve a total of 500K pictures.

Approval/Inactive

The experiment remains approved but inactive as of February 14, 1984. They have accumulated about 273K pictures as of June 1977.



Publications

Search for μe Events in Antineutrino-Nucleon Interactions. Phys. Rev. Lett. **38**, 266 (1977).

Scaling-Variable Distributions for Antineutrino-Nucleon Interactions. Phys. Rev. Lett. **39**, 382 (1977).

Probing Nuclei with Antineutrinos. Phys. Rev. D **18**, 1367 (1978).

Inclusive Negative-Hadron Production from High-Energy $\bar{\nu}$-Nucleus Charged-Current Interactions. Phys. Rev. D **18**, 3905 (1978).

The Production of μe Events in Antineutrino-Nucleon Interactions. Phys. Lett. B **81**, 89 (1979).

A Search at High Energies for Antineutrino-Electron Elastic Scattering. Phys. Lett. B **84**, 357 (1979).

$\bar{\nu}_\mu p$ and $\bar{\nu}_\mu n$ Charged-Current Interactions Unfolded From High Energy $\bar{\nu}_\mu$ Interactions in Neon. Phys. Lett. B **84**, 511 (1980).

Search for a Charm Changing Neutral Current in Antineutrino Interactions. Phys. Lett. B **88**, 181 (1979).

A Study of Semi-Inclusive Gamma Production in Charged-Current Antineutrino-Nucleon Interactions. Nuovo Cimento A **51**, 539 (1979).

Nuclear Effects in High-Energy Antineutrino Interactions. Phys. Rev. D **22**, 2581 (1980).

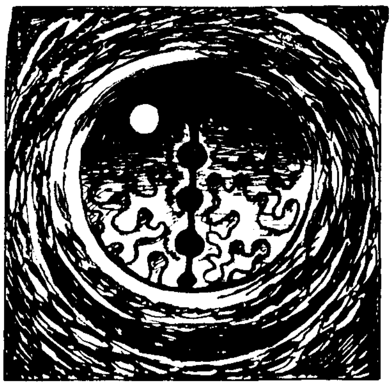
Net Charge in Deep Inelastic Antineutrino-Nucleon Scattering. Phys. Lett. B **91**, 311 (1980).

Measurement of SU(3) Symmetry Violation in the Quark Jet. Phys Lett. B **93**, 210 (1980).

Properties of K^0 and Λ Inclusive Production in Charged-Current Antineutrino-Nucleon Interactions. Nuc. Phys. B **162**, 205 (1980).

Average Transverse Momentum Behavior of Charged Hadrons in Charged Current Antineutrino-Nucleon Interactions. Phys. Lett. B **102**, 213 (1981).

Looking for $\bar{\nu}_\mu \to \bar{\nu}_\tau$ Oscillations. Phys. Lett. B **105**, 301 (1981).



Observation of $\mu^+ e^+$ Events in Antineutrino-Nucleon Interactions. Phys. Lett. B **106**, 151 (1981).

Charged Current Events With Neutral Strange Particles in High-Energy Antineutrino Interactions. Nuc. Phys. B **177**, 365 (1981).

Quark Jets from Antineutrino Interactions. Nuc. Phys. B **184**, 13 (1981).

Inclusive Charged-Current Antineutrino-Nucleon Interactions at High Energies. Nuc. Phys. B **199**, 399 (1982).

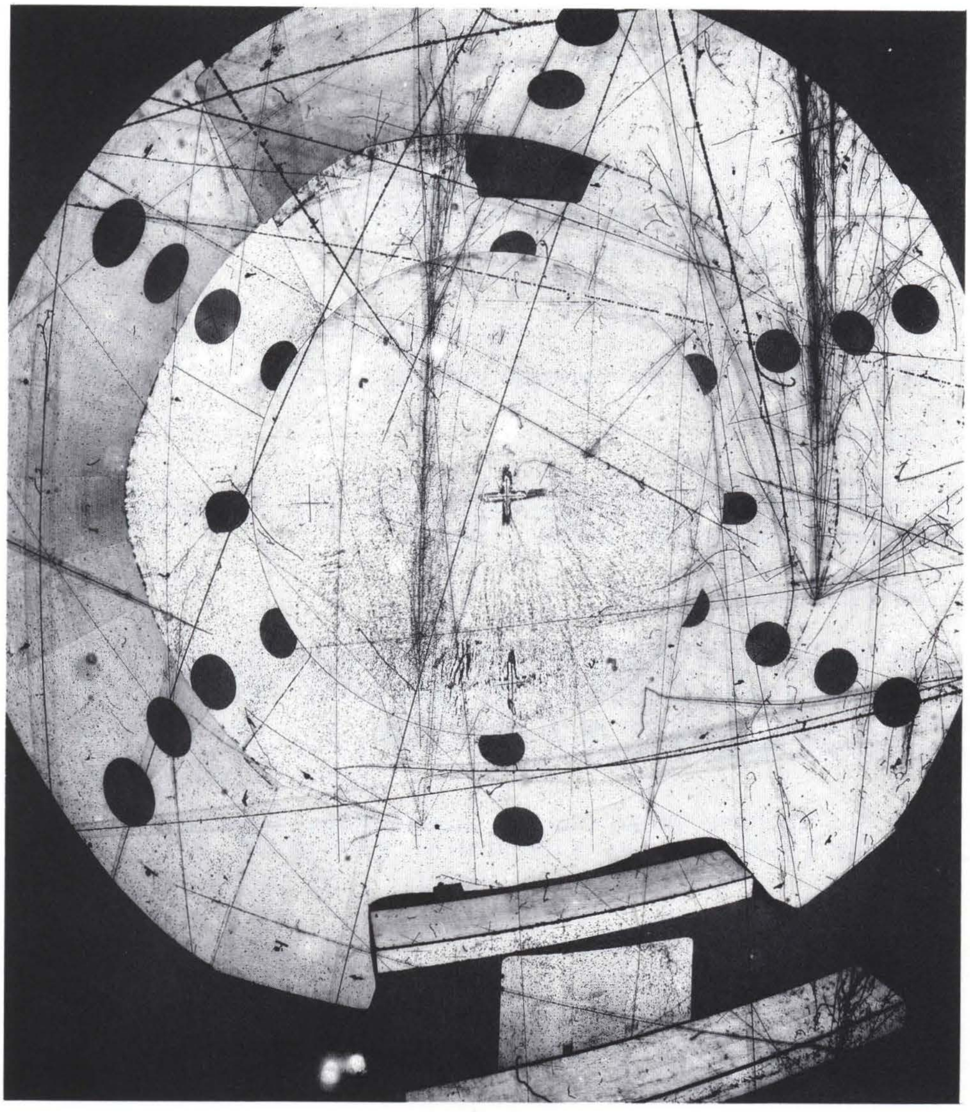
Quark Jets From Antineutrino Interactions. Nuc. Phys. B **203**, 1 (1982).

Quark Jets From Antineutrino Interactions. Nuc. Phys. B **203**,16 (1982).

Total Antineutrino-Nucleon Charged Current Cross Section in the Energy Range 10-50 GeV. Phys. Lett. B **137**, 122 (1984).

Neutral Currents in the Antineutrino Experiment in the 15-Foot Bubble Chamber. Sov. J. Nucl. Phys. **39**, 396 (1984).

Nuclear-Emulsion Observation of the Decay of a Charmed $\Sigma_c{}^0$ Baryon Into $\Lambda_c{}^+\pi^-$ Followed by a $\Lambda_c{}^+$ Decay into $\Sigma^+\pi^-\pi^+$. JETP Lett. **43**, 515 (1986).



8) Experiment E-202

Spokesman: David F. Bartlett
Beamline: Neutrino Area Miscellaneous

Institutions

Colorado, University of
Princeton University

Physics Goals

This experiment involved a search for tachyon monopoles with cosmic rays above the 15 Foot Bubble Chamber. Neither the Bubble Chamber itself nor neutrino beams from the Fermilab accelerator were used. The experiment used the magnetic field of the 15 Foot Bubble Chamber Magnet.

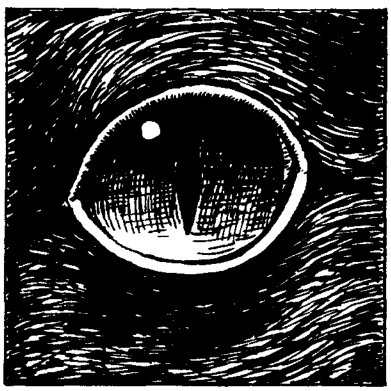
Request

The experiment's request was submitted on February 1, 1973 with 800 hours of running, of which half would be with zero field in the 15 Foot Bubble Chamber Magnet.

Approval

E-202 was approved for parasitic running on August 22, 1973.

Completion



The experiment was completed on May 19, 1976 and accumulated a data sample induced by cosmic rays.

Publications

Search for Tachyon Monopoles in Cosmic Rays. Invited talk at the 18th International Conference on High-Energy Physics, Tbilisi, USSR 7/76 (N. Bogolubov et al eds. Dubna, 1977) vol. II, pp. N24-N26.

Search for Tachyon Monopoles in Cosmic Rays. Phys. Rev. D **18**, 2253-2261 (1978).

9) Experiment E-234 (Engineering Run)

Spokesman: Fred Russ Huson
Beamline: Neutrino Area 15 Foot Hadron Beam

Institutions

Fermi National Accelerator Laboratory
Florida State University

Physics Goals

This was an engineering run for the 15 Foot Cryogenic Bubble Chamber, a tangential goal being the study of π^-/proton interactions at 250 GeV.

Request

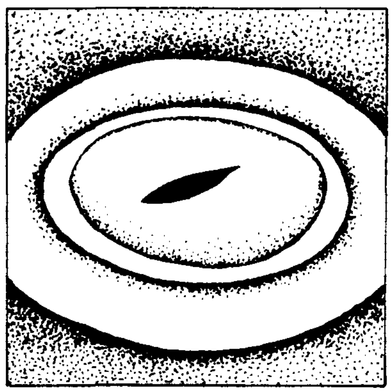
The experiment filed their request on August 1, 1973 asking for a data sample of 50K pictures.

Approval

Approval was forthcoming on August 6. 1973 with an allocation for the requested 50K pictures.

Completion

The experiment was completed on November 5, 1974, having accumulated a total data sample of 57K pictures.



Publications

Inclusive Production of Neutral Strange Particles in 250-GeV/*c* π^-p Interactions. Phys. Rev. D **16**, 2098 (1977).

Two-Particle Correlations Involving Neutral Strange Particles. Phys. Rev. D **18**, 92 (1978).

250-GeV/*c* π^-p Multiplicity Distributions and the Two-Component Model. Phys. Rev. D **23**, 20 (1981).

10) Experiment E-341 (P - P @ 400)

Spokesman: Winston Ko
Beamline: Neutrino Area 15 Foot Hadron Beam

Institutions

California, University of, Davis
Lawrence Berkeley Laboratory

Physics Goals

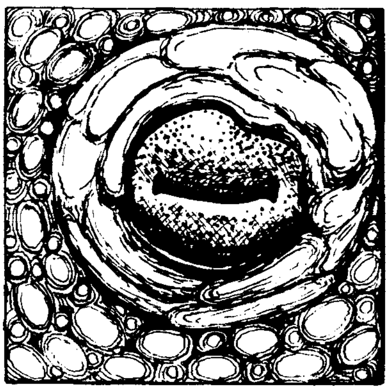
E-341's goal was the study of the interaction of π^+ mesons and protons in a hydrogen/neon mixture.

Request

The experiment requested 100K pictures on October 1, 1974.

Approval

Their request was approved on December 4, 1974, with 25K pictures allocated for interactions with both tagged p+ and proton beams at 150 GeV in hydrogen, with the goal of defining techniques for analyzing 15 Foot Bubble Chamber film. On December 8, 1975, the experiment was subsequently allocated another 25K pictures of proton-proton interactions at 400 GeV.



Completion

December 21, 1975 marks the formal completion of the experiment with a total of 34K pictures taken.

Publications

Charged- and Neutral-Particle Production from 400-GeV/*c* *pp* Collisions. Phys. Rev. D **19**, 605 (1979).

11) Experiment E-343 (P - P @ 300)

Spokesman: Roderich J. Engelmann
Beam: Neutrino Area-15-Foot Hadron Beam

Institutions

Argonne National Laboratory
Kansas, University of
New York, University of, Stony Brook
Tufts University

Physics Goals

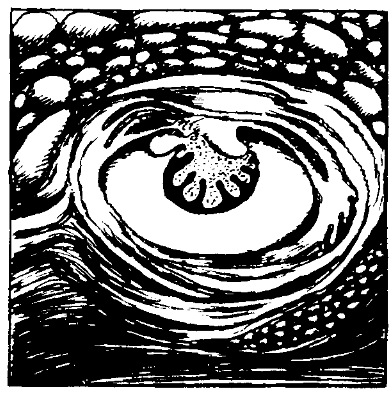
This experiment was a proposal to study neutral particle production in 250 GeV proton-proton interaction.

Request

The experiment requested 25K pictures on October 3, 1974.

Approval

December 4, 1974, the experiment was approved and allocated 25K pictures.



Completion

E-343 was completed on January 13, 1976 with a total data sample of 27K pictures.

Publications

Correlations Between Neutral and Charged Pions Produced in 300-GeV/ *c pp* Collisions. Phys. Rev. D **19**, 76 (1979).

Inclusive K^o, Λ^o, $K^{*\pm}(890)$, and $\Sigma^{*\pm}(1385)$ Production in *pp* Collisions at 300 GeV/*c*. Phys. Rev. D **22**, 573 (1980).

12) Experiment E-380 (Neutrino/N2&NE)

Spokesman: Charles Baltay
Beamline: Dichromatic Neutrino Beam

Institutions

Brookhaven National Laboratory
Columbia University

Physics Goals

This experiment was a study of the properties of weak neutral currents in the interactions of a narrow-band neutrino beam in liquid neon.

Request

The experiment requested 200K pictures on February 6, 1975.

Approval

The experiment was approved to run on July 7, 1975, being allocated 200K pictures in a heavy neon-hydrogen mixture. This was contingent upon the construction and adequate performance of an improved narrow-band neutrino beam. the experiment was subsequently approved for an additional 200K pictures on June 24, 1977 to be taken at higher energies using the D C dichromatic train.

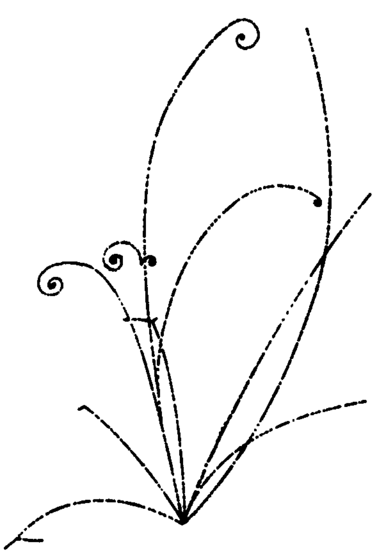
Completion

The experiment was completed on October 31, 1979, having accumulated a total data sample of 196K pictures.

Publications

Measurement of the ν_μ Charged-Current Cross Section. Phys. Rev. Lett. **51**, 735 (1983).

Limits on Neutrino Oscillations in the Fermilab Narrow-Band Beam. Phys. Rev. D **34**, 2183 (1986).



13) **Experiment E-388** (Anti-Neutrino/N2&NE)

Spokesman: Vincent Z. Peterson
Beamline: Dichromatic Neutrino Beam

Institutions

Fermi National Accelerator Laboratory
Hawaii, University of
Lawrence Berkeley Laboratory

Physics Goals

Experiment E-388 was a proposal to study neutral current neutrino and anti-neutrino interactions using the external muon identifier and a dichromatic beam.

Request

The experiment made two requests. The first was on April 24, 1975 with a requested 200K pictures, with the second being on June 7, 1978, involving 500K pictures or 5×10^{18} protons on the primary production target.

Approval

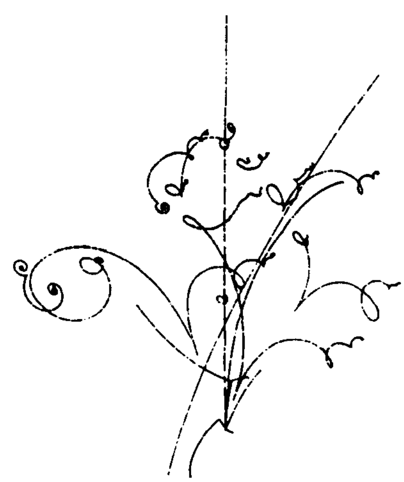
The experiment was first approved on July 7, 1975, with an allocation of 200K pictures of antineutrino interactions with a heavy neon-hydrogen mixture. This was contingent upon the construction and adequate performance of an improved narrow-band beam. The experiment was approved to run a second time on June 24, 1977, with an allocation of 200K pictures taken at higher energies, using the D C dichromatic train. This was also with the understanding that new requests for the use of the dichromatic train would be considered at a later time. Finally, after a second request was submitted (see above), on June 28, 1978 a decision was reached to maintain the present approval as it was, namely 200k pictures.

Completed

The experiment was completed on September 12, 1979 and accumulated a total data sample of 181K pictures.

Publications

$\bar{\nu}_\mu$-Nucleon Charged-Current Total Cross Section for 5-250 GeV.
Phys. Rev. Lett. **51,** 739 (1983).



Limits on the Neutrino Oscillations $\overline{\nu}_\mu \rightarrow \overline{\nu}_e$ and $\overline{\nu}_\mu \rightarrow \overline{\nu}_\tau$ Using a Narrow-Band Beam. Phys. Rev. D **28**, 2705 (1983).

14) **Experiment E-390** (Anti-Neutrino/D2)

Spokesman: Arthur Garfinkel
Beamline: Wide Band Horn Neutrino Beam

Institutions

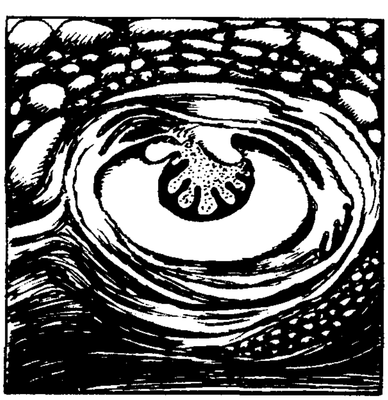
Argonne National Laboratory
Carnegie-Mellon University
Purdue University

Physics Goals

This experiment involved a study of anti-neutrino interactions in deuterium.

Request

The request was submitted on April 29, 1975, involving 300K pictures.



Approval

The first approval came on July 7, 1975, with an allotted 300K pictures. This was followed by a second action on June 28, 1978, involving 300K pictures with a total of 150K pictures being scheduled for the experiment during the run in the fall of 1978. Final approval came on March 19, 1979 with 250K pictures.

Approval/Inactive

E-390 was designated as inactive on October 26, 1981, having accumulated a data sample of 10K pictures.

15) Experiment E-502

Spokesman: David F. Bartlett
Beamline: Neutrino Miscellaneous

Institutions

Colorado, University of
General Electric Company Research & Development Center

Physics Goals

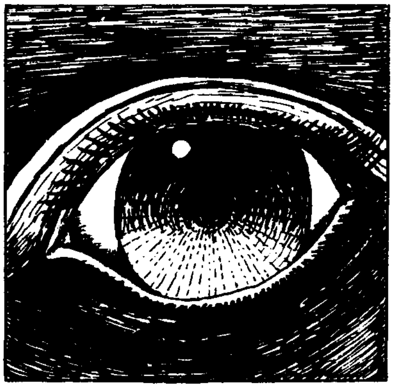
This experiment involved a search for monopoles above the 15 Foot Bubble Chamber. Neither the Bubble Chamber itself nor the Fermilab beam was used. The interactions resulted from cosmic rays and an interaction with the magnetic field of the 15 Foot Bubble Chamber Magnet. The experiment required a scuttle in the roof of the 15 Foot Bubble Chamber Building.

Request

On July 30, 1976, the experiment requested that the parasitic cosmic ray running include the fringe field of the 15 Foot Bubble Chamber Magnet during 2 long runs. This involved about 7 months of data taking with lexan and later data to be taken with emulsion detectors.

Approval

The experiment was approved on September 2, 1976 for parasitic running in the fringe field of the 15 Foot Bubble Chamber Magnet.



Completion

The experiment was completed on June 23, 1980 having accumulated a data sample induced by cosmic rays.

Publications

Search for Cosmic Ray Related Magnetic Monopoles at Ground Level. Phys. Rev. D **24**, 612-622 (1981).

16) Experiment E-545 (Neutrino/D2&HIZ)

Spokesman: George A. Snow
Beam: Wide Band Horn Neutrino Beam

Institutions

Illinois Institute of Technology
Maryland, University of
New York, State University of, Stony Brook
Tohoku University (Japan)
Tufts University

Physics Goals

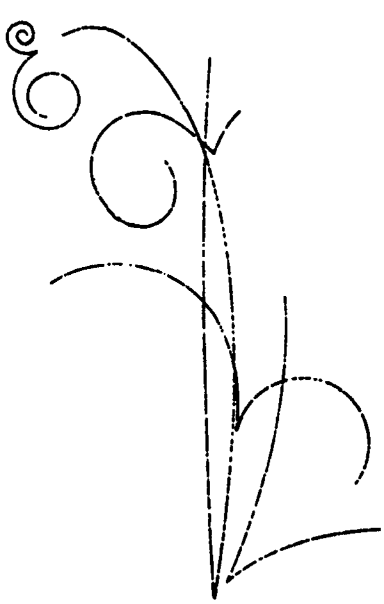
This was a proposal for an extension of the E-151/E-227 proposal to study neutrino interactions in deuterium with plates. The initial run was without plates.

Request

The experiment filed their request on April 18, 1977 requesting 300K pictures, but modified this request on December 21, 1977, increasing the number of pictures to 500K. The pictures were to be taken with the wide band neutrino beam and 1.3×10^{13} protons per pulse incident on the primary production target.

Approval

The experiment was approved on March 16, 1978 and allocated 350K pictures or equivalently 3.5×10^{18} protons incident on the primary production target. This was predicated upon the the successful test of the plate system. A second approval was given on June 8, 1978 for 350K pictures taken without the plates.



Completion

The experiment was completed on January 17, 1979, having accumulated a total data sample of 317K pictures.

Publications

Charmed-Baryon Production in High-Energy Neutrino-Deuterium Interactions. Phys. Rev. Lett. **45**, 955 (1980).

Comparison of νn and νp Charged-Current Cross Sections from High-Energy Neutrino Interactions in Deuterium. Phys. Rev. Lett. **45**, 1817 (1980).

Current and Target Jets Produced in High Energy Neutrino-Deuterium Interactions. Phys. Lett. B **97**, 325 (1980).

New Decay Mode of the Charmed Baryon, $\Lambda_c{}^+ \to \Sigma^0\pi^+$. Phys. Rev. Lett. **48**, 299 (1982).

Neutral-Current $\nu_\mu n$ and $\nu_\mu p$ Cross Sections from High-Energy Neutrino Interactions in Deuterium. Phys. Rev. Lett. **48**, 910 (1982).

Neutrino Flux and Total Charged-Current Cross Sections in High-Energy Neutrino-Deuterium Interactions. Phys. Rev. Lett. **49**, 98 (1982).

Charmed-Baryon Production in $\nu d \to \mu^-\Lambda X$ Reactions. Phys. Rev. Lett. **49**, 1128 (1982).

Charged-Particle Multiplicity Distributions in νn and νp Charged-Current Interactions. Phys. Rev. D **27**, 47 (1983).

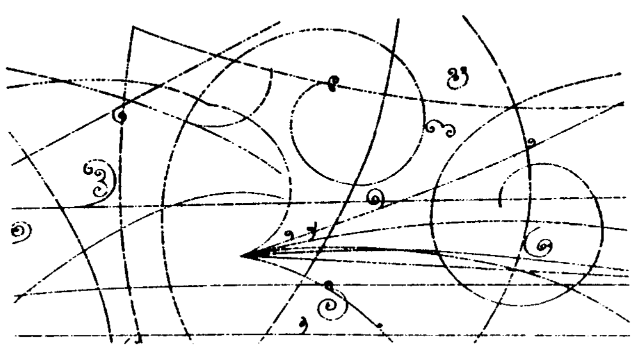
Study of Diquark Fragmentation into Λ and Y^{*+} in νn and νp Interactions. Phys. Rev. D **27**, 2776 (1983).

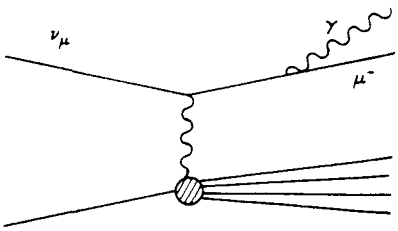
High-Energy Quasielastic $\nu_\mu n \to \mu^- p$ Scattering in Deuterium. Phys. Rev. D **28**, 436 (1983).

Quasielastic Charmed-Baryon Production and Exclusive Strange-Particle Production by High-Energy Neutrinos. Phys. Rev. D **28**, 2129 (1983).

Comparison of Cross Sections from Deep-Inelastic Neutrino Scattering on Neon and Deuterium. Phys. Rev. D **32**, 2441 (1985).

Nonsinglet Valence-Quark Distribution from Neutrino-Deuterium Deep-Inelastic Scattering. Phys. Rev. D **37**, 1105 (1988).





17) Experiment E-546 (Neutrino/H2&NE)

Spokesman: Fred Russ Huson
Beamline: Quad-Triplet Neutrino Beam

Institutions

California, University of Berkeley
Fermi National Accelerator Laboratory
Hawaii, University of
Lawrence Berkeley Laboratory
Washington, University of
Wisconsin, University of, Madison

Physics Goals

This experiment will study high-energy neutrino and antineutrino interactions using the quad-triplet train load and the two-plane EMI.

Request

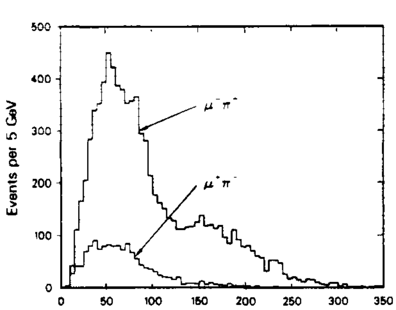
The request was submitted on April 27, 1977 for 250K pictures, with specific interest in an exposure of 5×10^{18} protons.

Approval

The experiment was approved on June 29, 1977 for parasitic running, concurrent with other neutrino areas experiments running with the quad-triplet train.

Completion

The experiment was completed on January 26, 1978 with a data sample of 375K pictures.



Publications

A Neutrino (Antineutrino)-Induced Four Lepton Event. Phys. Lett. B **78**, 505 (1978).

Dimuon Production by Neutrinos in the Fermilab 15-Foot Bubble Chamber. Phys. Rev. D **21**, 569 (1980).

Observation of Short-Lived Particles Produced in High Energy Neutrino Interactions. Phys. Lett. B **89**, 423 (1980).

Evidence for Hard-Gluon Bremsstrahlung in a Deep-Inelastic Neutrino Scattering Experiment. Phys. Rev. Lett. **47**, 556 (1981).

Dilepton Production by Neutrinos in the Fermilab 15-Foot Bubble Chamber. Phys. Rev. D **24**, 7 (1981).

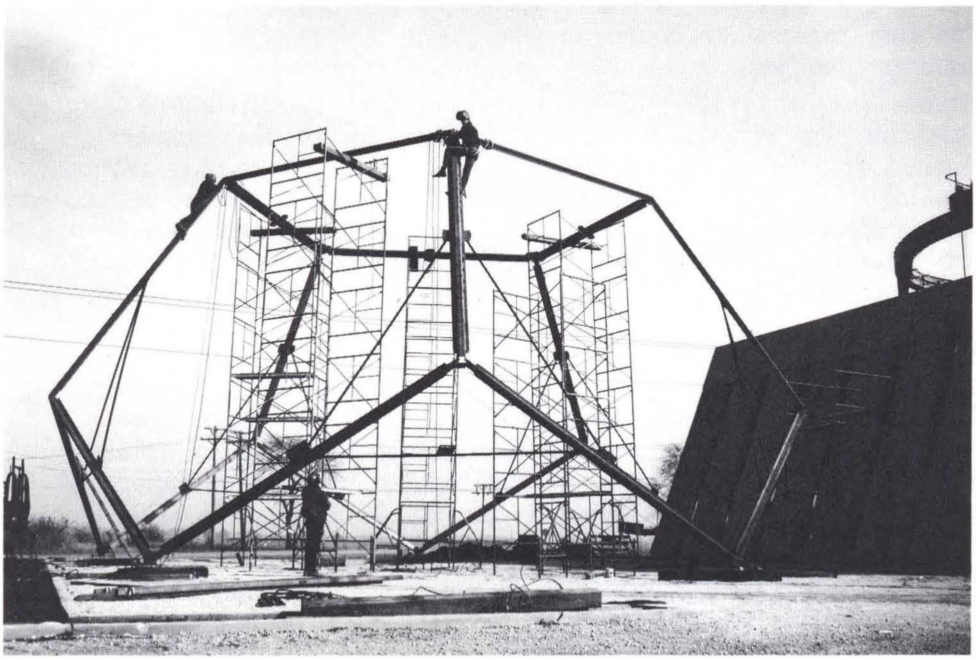
Observation of Muon Inner Bremsstrahlung in Deep-Inelastic Neutrino Scattering. Phys. Rev. Lett. **50**, 1963 (1983).

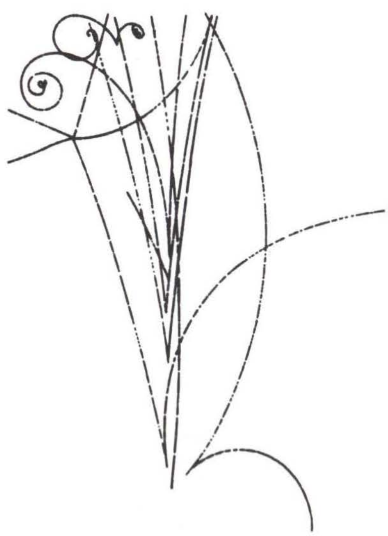
Search for Narrow $\mu^+ \pi^\pm$ Mass Enhancements in a Neutrino Bubble-Chamber Experiment. Phys. Rev. D **29**, 1300 (1984).

Hadron Up-Down Asymmetry in Neutrino-Neon Charged-Current Interactions. Phys. Rev. D **30**, 1130 (1984).

Search for High-Energy Tau-Neutrino Interactions. Phys. Rev. D **30**, 2271 (1984).

Coherent ρ^+ Production in Neutrino-Neon Interactions. Phys. Rev. D **37**, 1744 (1988).





18) Experiment E-564 (Emulsion/Neutrino)

Spokesman: Louis Voyvodic
Beam: Wide Band Horn Neutrino Beam

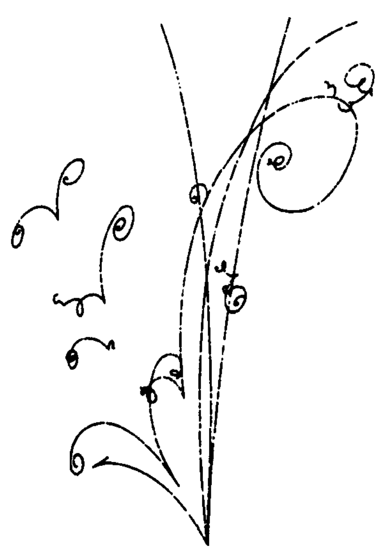
Institutions

Fermi National Accelerator Laboratory
Illinois Institute of Technology
Institute of Theoretical & Experimental Physics, Moscow (USSR)
Institute of High Energy Physics, Serpukhov (USSR)
Institute of Nuclear Physics, Cracow (Poland)
Joint Institute for Nuclear Research, Dubna (USSR)
Kansas, University of
Nuclear Physics, University of, Sofia (Bulgaria)
Sydney, University of, Sydney (Australia)
Washington, University of

Physics Goals

This experiment proposed to study the direct detection of short-lived particles from interactions in nuclear emulsions inside the 15 Foot Bubble Chamber.

Request



The first request was made on May 11,1977 for 1,500 hours of running time with a specific request for neutrinos from a total proton flux of $3x10^{18}$ incident on the primary production target. This run was proposed with a deuterium fill of the chamber planned for the spring of 1978. On May 8, 1979 another request was made for 1,100 hours of additional running time to be carried out parasitically in the 15 Foot Bubble Chamber. The film from two auxiliary cameras was requested for the neutrino portion of the running period.

Approval

The experiment was approved on June 24, 1977 for parasitic running, with the understanding that the experiment would impose only a small impact on the regular 15 Foot operations. A subsequent approval was granted on July 1, 1979, also with the understanding that the experiment would impose only a small impact on the regular 15 Foot operations.

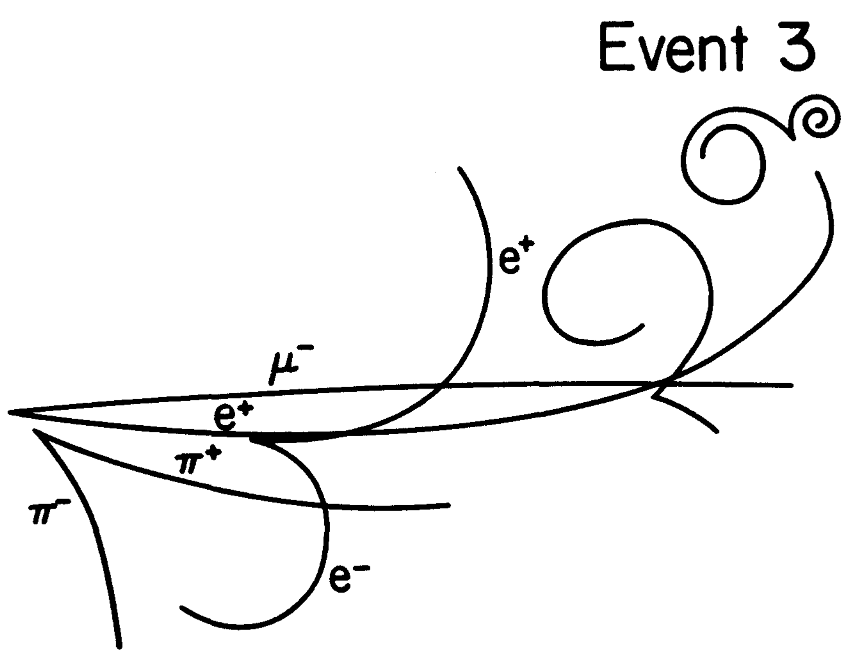
Completion

The experiment was completed on March 9, 1981, having accumulated a total data sample of 277K pictures.

Publications

Production And Decay of $F^+(2030)$ Observed in ν_μ Interactions in Emulsion. Phys. Lett. B **94**, 118 (1980).

Neutrino Interaction in Emulsion Stacks Inside the Fermilab 15-Foot Bubble Chamber. Acta Phys. Polon. B **17**, 41 (1986).



19) Experiment E-632 (Neutrino/H2&NE)

Spokesmen: Douglas R.O. Morrison and Michael W. Peters
Beamline: Neutrino Area Center

Institutions

Birmingham, University of (Great Britain)
Brussels, Universite Libre De (Belgium)
California, University of, Berkeley
CEN-Saclay (France)
CERN (Switzerland)
Fermi National Accelerator Laboratory
Hawaii, University of
Illinois Institute of Technology
Imperial College, London (Great Britain)
Jammu University, Jammu-Tawi (India)
Max-Planck Institute, Munich (Germany)
Oxford, University of (Great Britain)
Punjab University, Chandigrah (India)
Rutgers University
Rutherford Appleton Labs (Great Britain)
Tufts University

Physics Goals

This experiment exposed the 15 Foot Bubble Chamber (with a neon-hydrogen mixture) to a wideband neutrino beam produced by protons from the Tevatron.

Request

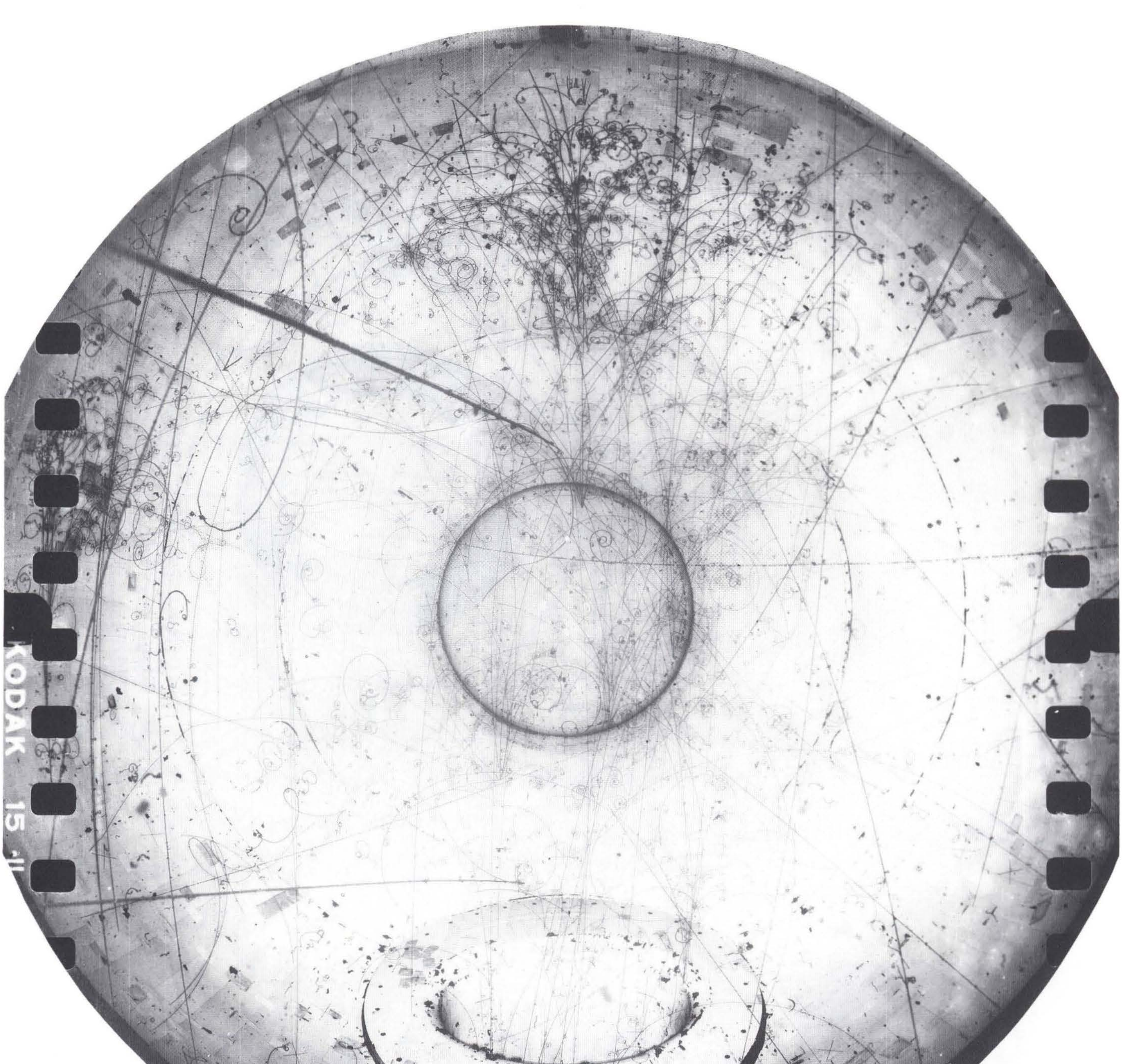
The request was filed on April 25, 1980 requesting 250K pictures.

Approval

The experiment was approved on June 18, 1982 with stage I approval for $1x10^{18}$ protons incident on the primary production target. Stage II approval was given on December 15, 1983, also with $1x10^{18}$ protons incident on the production target.

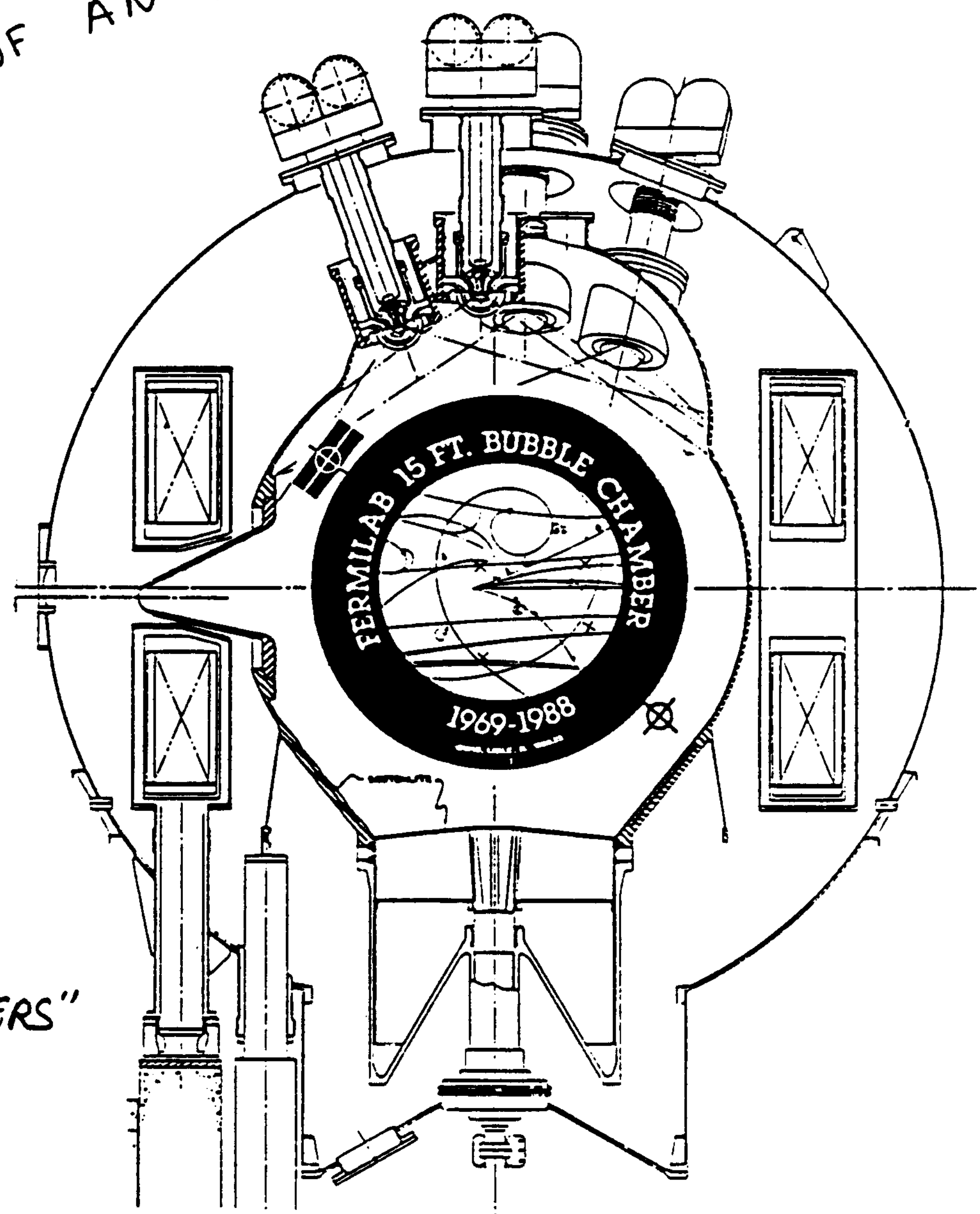
Completion

The experiment was completed on February 1, 1988 with a total data sample of 447K pictures.


KODAK 15

FIFTEEN FOOT FEST

END OF AN ERA CELEBRATION



HONORING

THE BUBBLE MAKERS"

FRIDAY, APRIL 8, 2:30-7:30 PM

AT THE **VILLAGE BARN**

AN "OLD FASHIONED BUBBLE CHAMBER PARTY"

BEER, POP, FOOD - TESTIMONIALS & ANECDOTES

Appendix B

Greetings and Salutations

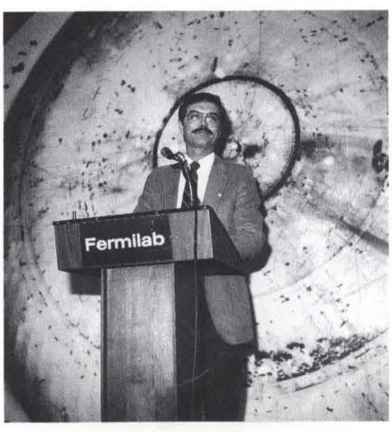
This Appendix contains the letters, memos, and telexes that were sent by those who could not attend the 15 Foot Fest activities, but who wanted to remember and honor those individuals who contributed to the success of the chamber.

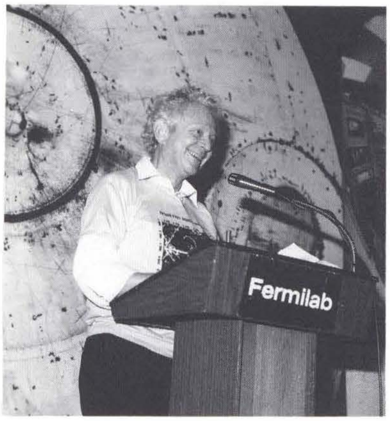
April 8, 1988

Dear Thornton, Wes, and Colleagues,

Thank you for inviting me to the
Fifteen Foot Fest!
Sorry, I can't be with you.
Congratulations from one who had the chance to analyze film from one of the first experiments (E 28 in 1975) and from the last experiment (E 632, where he even was allowed to use a screw driver in the E.M.i.).
Next page shows the first $\mu^- e^+ K^\circ$.. event found on E28-film here at CERN and page 3 is the only (?) event of its kind ever seen.
Best wishes for new activities!

Horst Wachsmuth
CERN - EP





Date: Fri, 18 Mar 88 15:50 CST
Original_From: Jnet%"ROE@UMIPHYS"
Comments: This is gatewayed mail. Warning: Mail may not necessarily be returnable through this path.
From: General Delivery <POSTMASTER@FNAL>
Subject: FIFTEEN FOOT FEST!!!! Have a great party.
To: b94094@FNALVM

Received: From UMIPHYS(ROE) by FNAL with RSCS id 7525 for USERSOFFICE@FNAL; Fri, 18 Mar 88 15:49 CST
Date: Fri, 18 Mar 88 16:49 EDT
From: <ROE@UMIPHYS>
Subject: FIFTEEN FOOT FEST!!!! Have a great party.
To: usersoffice@fnal

To: FIFTEEN FOOT FEST

From: Byron Roe, University of Michigan

Warm regards to all associated with the fifteen foot chamber over the many years it has run! Teaching duties make it very difficult to get away for the event but I thought I'd reminisce a bit anyway.

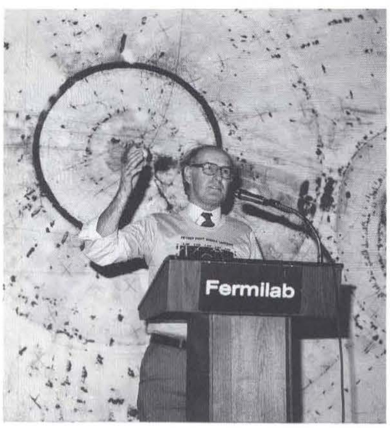
To begin with the physics was very good. That made it all fun. Some of the highlights of E45 and E180 on which I was co-spokesman were:

E45:

* First measurements of multiplicities and Feynman x distributions; first measurement of nu-p neutral current interactions; first measurement of the diffractive production of vector mesons in neutrino interactions (CVC); first real measurement of the cross-section and Q**2 dependence of nu p -->muminus piplus p and muminus kplus p (PCAC).
* Refereed publications: 7 Phys Rev Lett, 4 Phys Rev, 1 other.

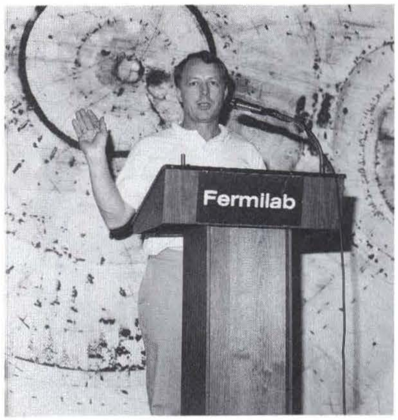
E180:

* Measurement of charmed particle production cross sections in nubar nucleon interactions; first verification of V-A nature of weak interactions in high energy electron neutrino interactions; first verification that charm changing neutral currents are forbidden; first measurement of scaling violation in high energy neutrino interactions; evidence against the "high y anomaly"; measurement of the suppression of the strange sea; limits on nubar e --> nubar e; first measurement of nubar n/nubar p cross sections for charged and neutral currents; measurement of the z-distributions fo pions from nubar nucleon interactions; limits on nubarmu --> nubartau oscillations.
* Refereed publications: 2 Phys. Rev. Lett, 8 Phys. Lett., 3 Phys. Rev., 6 others.



However, the things I remember are the smaller things, like the night shifts on the mezzanine with a few sleepy colleagus and the leaking roof for company. I was always exceedingly impressed with how well organized the chamber and the beam were as seen from the outside at least!

One of my collegues once went to look at the chamber and carefully removed his watch, but then later found his magnetic credit cards didn't work anymore. The chain hanging at a 30 degree angle or so was always an impressive sight.



A number of my colleagues and I will remember the group meetings we held half way between Fermilab and Michigan in a Schulers restaurant. A large number of our E180 decisions were made at a conference room there and then celebrated properly at the restaurant.

I also remember a trip to Moscow when a package of E180 test rolls vanished somewhere between Fermilab and Moscow. I kept wondering which secret service was looking at them and what they made of it all.

Most importantly there was a sense of adventure shared by the physicists and the technicians that made working on the exposures and working on the analysis a joy. Thanks for the memories.

===

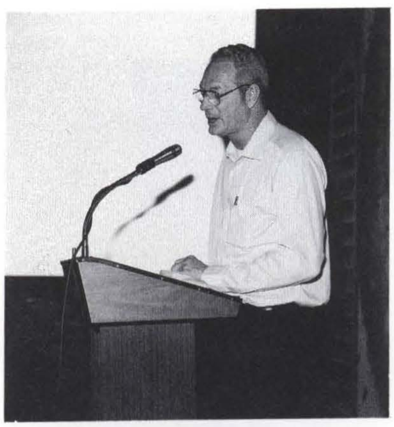
Message #5
RX TWX:*
NAL 314

83295 NUCLOX G

TO: DR C THORNTON MURPHY, FERMI NATIONAL ACCELERATOR LAB

FM: DR G MYATT, NUCLEAR PHYSICS LAB, OXFORD

UNFORTUNATELY I WILL NOT BE ABLE TO ATTEND THE FIFTEEN FOOT FEST. HOWEVER I WOULD LIKE TO TAKE THE OPPORTUNITY TO EXPRESS THE APPRECIATION OF THE OXFORD GROUP FOR THE FINE WORK CARRIED OUT AT FERMILAB BY THE ACCELERATOR AND BUBBLE CHAMBER TEAMS. THE IMPORTANT SCIENTIFIC RESULTS WHICH HAVE COME OUT OF PREVIOUS RUNS AND WHICH WILL COME OVER THE NEXT FEWS YEARS FROM ANALYSIS OF THE FINAL RUN, ARE A FITTING TRIBUTE TO THE SUCCESS OF THE FIFTEEN FOOT BUBBLE CHAMBER PROGRAM. WE WILL BE WITH YOU IN SPIRIT ON THE 8TH.



G MYATT.

NAL 314

83295 NUCLOX G
TO REPLY FROM TELEX I OR II (TWX) DIAL 100. FROM EASYLINK USE /WUW.
EST 0921 MAR/28/1988
time 272024 DISCONNECT
connect 151 secs listed 20:24 CDT 03/27/88

Yale University

PHYSICS DEPARTMENT
260 Whitney Avenue
P.O. Box 6666
New Haven, Connecticut 06511

April 7, 1988

Dear Thornton,

I am truly sorry that I cannot join you and our many colleagues whose lives - one way or another - were touched by the workings of the 15' chamber.

Please transmit my deep appreciation to the physicists and staff who created the enviable record of technical success and physics results.

With best wishes and congratulations to all!

Jack Sandweiss

Message #56
RX TLX:
0659 EDT
NAL 314

412657 IPHE SU

TO: C.T. MURPHY,
FERMILAB, USA

IT WAS A PITY TO FIND OUT ABOUT THE COMPLETION OF THE FIFTEEN FOOT BUBBLE PROGRAM AT TEVATRON. WE ALWAYS CONSIDER THIS CHAMBER AS THE BEST EXAMPLE OF THE STATE OF ENGINNRIC ART. CERTAINLY TO PRODUCE BUBBLES WITH SUCH KIND OF THE TOOL IS RATHER EXPENSIVE JOB BUT AS SCIENTIFIC RESULTS SHOW THIS JOB BY NO MEANS IS NOT USELESS. FIFTEEN FEET OF THE CHAMBER-FIFTEEN STEPS TOWARD THE KNOWLEDGE OF THE PROPERTY OF THE MATTER. WE ALWAYS WILL REMEMBER ALL PAST YEARS OF OUR COLLABORATION AND HIGHLY ESTIMATE THE PHYSICAL RESULTS OBTAINED TOGETHER IN EXPERIMENTS E45, E180 AND E564.
WITH BEST WISHES TO PARTICIPANTS OF FIFTEEN FOOT FEST.
ON BEHALF OF THE SOVIET COLLEAGUES

V. YARBA, V. AMMOSOV, O. MIKHAILOV, YU. RJABOV, A. MUKHIN,
V. SIROTENKO

NAL 314

412657 IPHE SU

REPLY VIA 103

*
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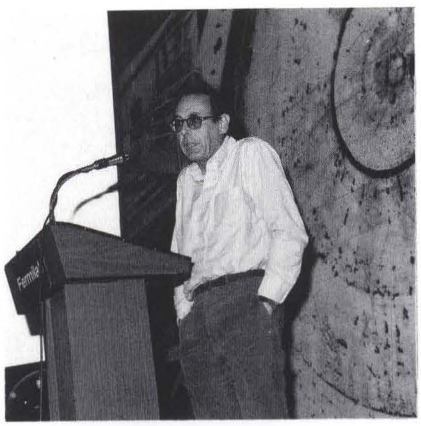
connect 174 secs listed 06:02 CDT 04/07/88



From: Jnet%"HIPHY007@TUFTS" 7-APR-1988 22:21
To: THORNTON
Subj: 15 FEET

Received: From TUFTS(HIPHY007) by FNAL with RSCS id 4743
for THORNTON@FNAL; Thu, 7 Apr 88 22:21 CDT
Date: Thu, 7 Apr 88 23:21 EST
From: <HIPHY007@TUFTS>
Subject: 15 FEET
To: THORNTON@FNAL
X-Original-To: THORNTON@FNAL, HIPHY007

8 April 1988

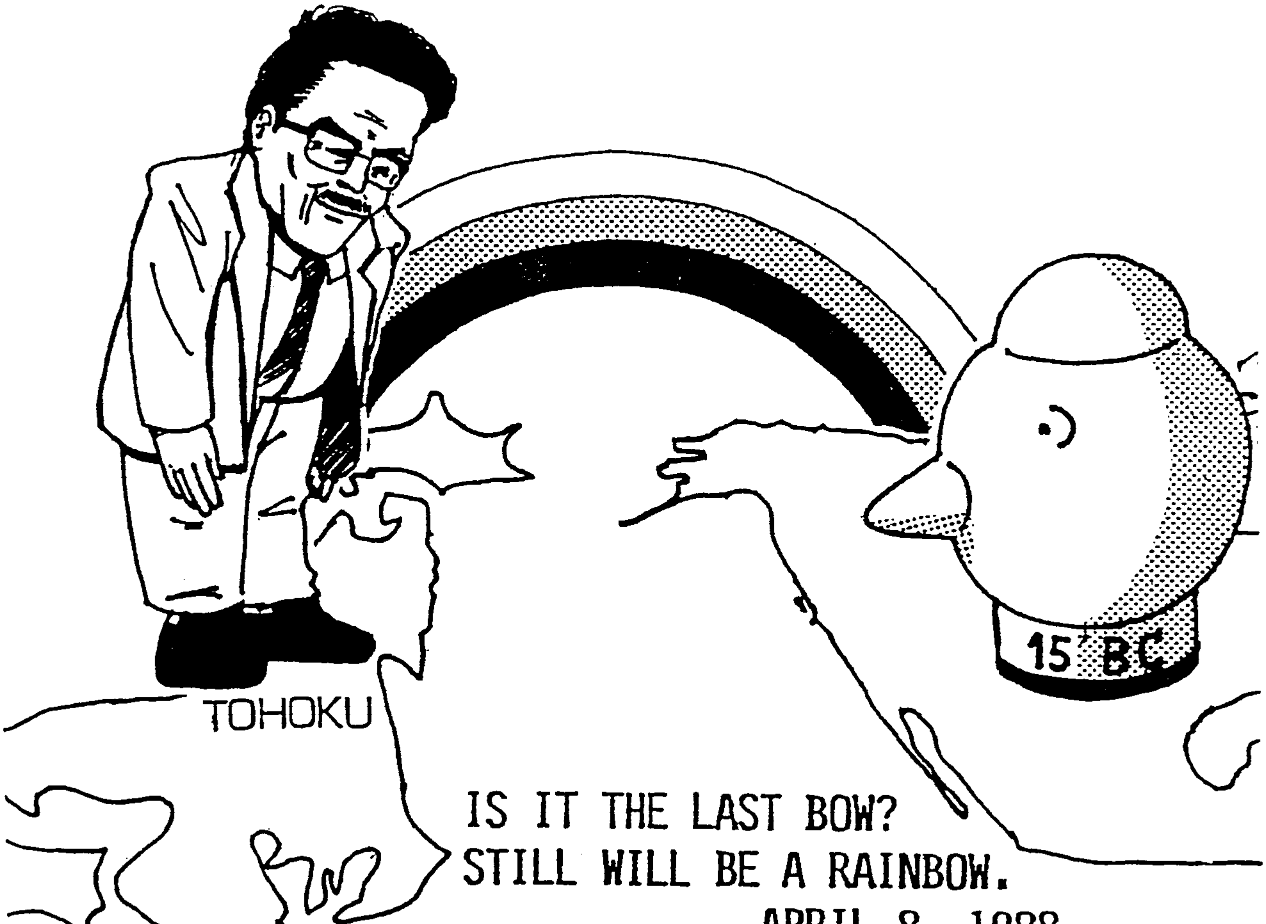
The Fifteen Foot was a very fine friend
Which now has come to its glorious end

Who knows but we may have cause to regret
That it didn't run a little longer yet
The "Beam Dump" we wanted,but couldn't get

But all is not gone, there will be something new
For the gang is still working on E632

Wish I could be with you at the party.Congratulations and best wishes to all of you for all the good years.

Jack Schneps



IS IT THE LAST BOW?
STILL WILL BE A RAINBOW.
APRIL 8 1988

15'BC USERS; E83 100GeV h^-
E545 350GeV ν-D

湯田春雄 Haru Yuta

森田欣之 Yoshiyuki morita

阿部浩也 Koya Abe

高山知明 Tomoaki Takayama

山口晃 Yamaguchi, Akira

花田博光 Hiromitu Hanada

増田博之 Hiroyuki Masuda

北垣敏男 Kitagaki Toshio

玉江京子 Kyoko Tamae

片山二満 Katayama Jimistu

古野貢一郎 Furuno, Koichiro

赤城卓 Takashi Akagi

中井聡 Nakai, Satoshi

中嶋隆 Takashi Nakajima

長谷川勝夫 Katsuo Hasegawa

田中昌 Tanaka, Syo

田口くに子 Taguchi, Kuniko

鈴木肇 Suzuki, Hajime

小林正 Kobayashi Tadashi

佐々木万亀夫 Makio Sasaki

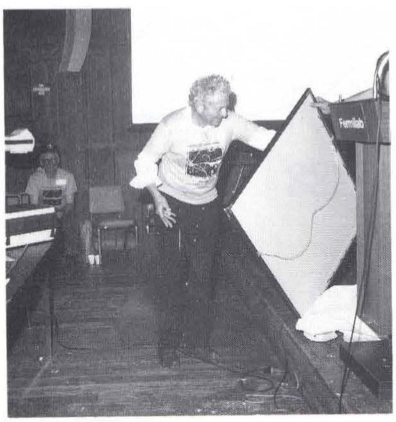
SURA

SOUTHEASTERN UNIVERSITIES RESEARCH ASSOCIATION, INC.
1776 MASSACHUSETTS AVENUE, NW, SUITE 604
WASHINGTON, DC 20036

April 8, 1988

Dr. Leon Lederman
Director
Fermi National Accelerator Lab.
P.O. Box 500
Batavia, Ill. 60510

Dear Leon:



My deepest regrets at being unable personally to join you today in honor of all the individuals who made the bubble chamber such a productive instrument for frontier research. As I sit here on this rainy day in Washington, commiserating with myself for not being en route to Fermilab, several highlights quickly come to mind of individuals and events that led to those magnificent bubble chamber visualizations of the actions and interactions of the smallest, most fundamental parts of matter. Don Glaser, who just 35 years ago at Michigan discovered and developed the process and subsequently won a Nobel prize. Luis Alvarez and his group at Berkeley who made that tremendous direct extrapolation of the technology from chambers of a few centimeters size to the six-foot chamber - and the outstanding research program subsequently carried out at LBL and SLAC - also a Nobel prize for Luis. Tom Fields and his Northwestern group working at ANL and developing the first bubble chamber in a superconducting magnet. Ralph Shutt and his group at BNL and the many technical developments and physics results coming from their work, including the seven-foot "test facility" - also the discovery of the Omega-minus by Nick Samios, et al. Gale Pewitt and his colleagues who gulped several times then bravely led the way for the future with the superconducting coils and twelve-foot bubble chamber at ANL. Bob Wilson, Russ Huson, Bill Fowler, George Mulholland and others at Fermilab who had the vision, led the design and construction and the very successful operation and use of the magnificent fifteen-foot facility whose retirement is commemorated today. I'm reminded also of Andy Mravca and our other DOE colleagues who shared the vision and worked hard to help make it all possible.

Please give my warm regards, best wishes and regrets at being unable to be with them to those at the commemoration this afternoon.

Sincerely

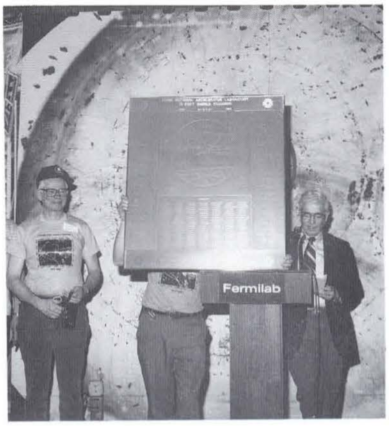
Bill

William A. Wallenmeyer
President

(202) 457-0381

BITNET: SURA @ UMDC

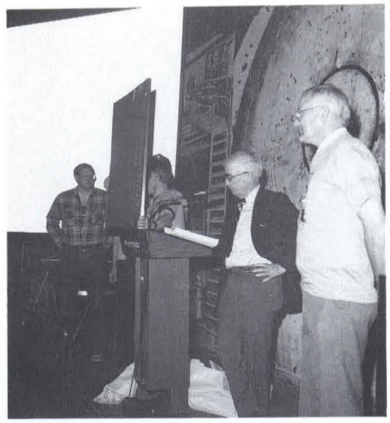
2 April 1988



Wes Smart
Bubble Chamber Group
Fermi National Accelerator Laboratory
Batavia, Illinois 60510

Dear Wes and Friends,

The decommissioning symposium for the 15-foot Cryogenic Bubble Chamber to be held on Friday April 8th will mark the end of a great era for particle detectors. After 34 years of Bubble Chamber connections and the last 16 or so with the 15 foot, I see the 15 foot Bubble Chamber as the Jewel in the Crown, if I may borrow a phrase.



As I see it the 15-foot Bubble Chamber operation was scientifically very successful. Bill Fowler got the project off to a fast start with his ingenious idea of involving other national laboratories, universities and industry to work successfully on many of the major components which allowed Fermilab to focus on the scientific, data collection and installation. Equally important was the fact that this very large complex and potentially hazardous device was operated over its whole lifetime without any accident serious enough to get the laboratory management out of bed. The crew and the crew chiefs deserve the credit for perservering through many long tough shifts.

It is right to pause and reflect on this successful accomplishment. Anyone who has contributed to the success of the Fermilab 15-foot Cryogenic Bubble Chamber project has just got to feel good about it. The experience gained on this massive complex project puts you all in great demand for the new challenges that lie ahead.

I am very proud and happy to have had a part in the Fermilab15-foot Bubble Chamber experience. Sincerely,

Paul Hernandez
Lawrence Berkeley Labortory

Figure Captions

It should be pointed out that most of the pictures of bubble chamber tracks and track vignettes used in this book are used strictly for aesthetic purposes and are not illustrations of physics data. In addition, they are used without reference to context, i.e., experiment number.

Page ii- A portion of the geodesic dome which covers Lab A. Notice the honeycomb-like construction which utilized pop cans as part of the support structure.

Page iv- A front view of the 15 Foot Bubble Chamber before its installation in Lab B.

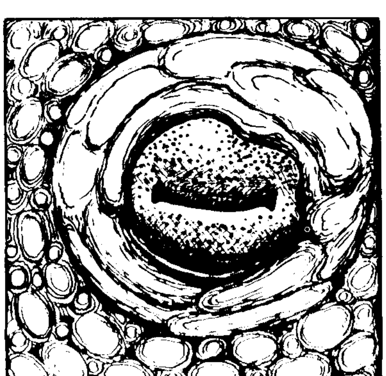
Page vi - This is a photograph of the first bubble chamber tracks taken on October 18, 1952 at the University of Michigan. The photograph is from Donald Glaser's laboratory notebook.

Page 2- (top to bottom) The Little European Bubble Chamber (LEBC) which ran for many years at CERN and also at Fermilab for experiment E-743 in the Meson Area.

A front view of CERN's Big European Bubble Chamber (BEBC). BEBC ran from 1973-1975 with CERN's Proton Synchrotron (PS) and from 1977-1985 with the Super Proton Synchrotron (SPS).

An inside view of BEBC.

A view of BEBC from the top of the chamber.



Page 3- (top to bottom) The 2-meter hydrogen bubble chamber which ran at CERN from 1965-1977.

The Gargamelle bubble chamber team with Paul Musset (left) who played a major role in the discovery of the neutral current (1973) and who was killed in a mountaineering accident in 1985.

Charles Peyron in the control room of CERN's 2-meter hydrogen bubble chamber.

Page 4- The 15 Foot Bubble Chamber being shipped to Fermilab by train.

Page 5- A photograph of the front cover of the Summer Study Volume 2, 1970. The original was drawn in pen and ink by Angela Gonzales.

Page 6- An event taken with the 15 Foot Bubble Chamber. A neutrino enters the chamber from the bottom of the picture and traverses a portion of the volume undetected, then interacts causing a decay vertex in the center of the photograph.

Page 9- A typical midnight shift as recorded in the 15 Foot Bubble Chamber Crew Chief's logbook indicating the status of the chamber and picture taking.

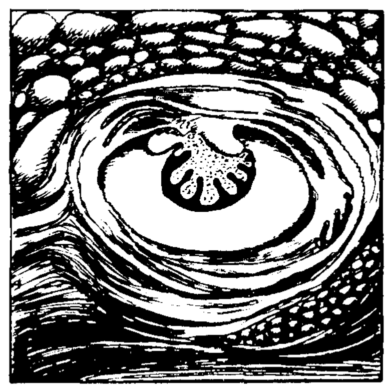
Page 10- Preparations for the assembly of the vacuum tank which enclosed the 15 Foot Bubble Chamber. The building in which the chamber was finally housed (Lab B) is not pictured here, but is located a short distance to the right of the photograph.

Page 12- The first 15 Foot Bubble Chamber operations crew. Pictured are (left to right and top to bottom) Bob Stover, George Athanasiou, Chuck McNeal, John Foglesong, Asa Newman, John Stoffel (seated), George Simon, Dennis Curtis, Arnold Coleman, Jim Kilmer, Bill Noe Sr., Dick Almon.

Page 13- The first 15 Foot Bubble Chamber operations crew. Pictured are (left to right and top to bottom) Gene Beck, Ron Davis, Frank Bellinger, John Colvin, Colby Pitts, Steve Johnston, John Woodworth, Wes Smart, Randy Thompson, Bob Ferry, Jim White, Stan Tonkin, Jerry Kadow.

Page 14- The 15 Foot Bubble Chamber as it sat in its vacuum tank housing in Lab B.

Page 16- C. Thronton Murphy with Leon Lederman, preparing to present the 15 Foot Commemorative Plaque to Bill Fowler at the conclusion of the 15 Foot Fest presentations.



Page 17- A picture of an event in the 15 Foot Bubble Chamber.

Page 18- The cover page from the original 25-Foot Bubble Chamber Design Report which was originally drawn in pen and ink by Angela Gonzales.

Page 23- An event vertex in the 15 Foot Bubble Chamber.

Page 24- An event in the 15 Foot Bubble Chamber.

Page 26- One of the overheads made by Charles Baltay for his 15 Foot Fest presentation.

Page 30- A pen and ink drawing by Angela Gonzales which shows the the Fermilab accelerator, Central Lab and fixed-target experimental areas.

Page 34- A pen and ink drawing by Angela Gonzales which depicts the Fermilab site covered by heavy clouds. The geodesic dome is visible in the lower left portion of the page.

Page 36- Technicians work on the 15 Foot Bubble Chamber magnet coil while (L-R) Hans Kautzky, Russ Huson, and John Purcell discuss an engineering issue.

Page 39- Operation of the 15 Foot demanded a steady stream of gas deliveries, especially liquid hydrogen and neon. Pictured are Paul Thorkelson (L) and Larry Bingham.

Page 40- A collage done by Angela Gonzales depicting an impressionistic view of the early stages of the 15 Foot construction.

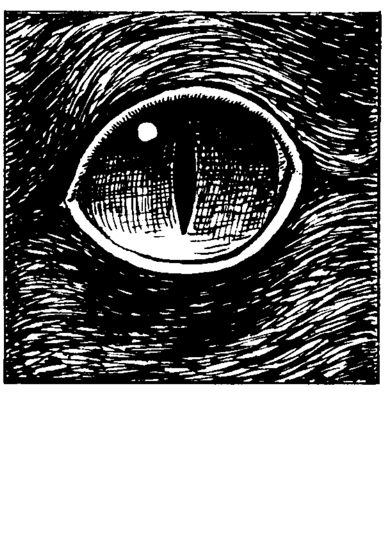
Page 43- A photograph of the mesh that supported the super insulation on the inside wall of the vacuum tank.

Page 44- A Photograph of the 15 Foot Bubble Chamber piston. The cylinder is pictured in the lower right hand corner.

Page 50- A photograph of an event taken with the 15 Foot Bubble Chamber.

Page 54- The vacuum tank that enclosed the 15 Foot Bubble Chamber is lowered into its position on top of the chamber.

Page 58- The inside top of the 15 Foot Bubble Chamber.



Page 59- An hemispherical window through which events which occurred inside the 15 Foot Bubble Chamber were photographed.

Page 60- The 15 Foot Bubble Chamber.

Page 62- Russ Huson (L) and Bill Fowler are greeting the 15 Foot Bubble Chamber upon its arrival at the National Accelerator Laboratory (The name was changed to Fermi National Accelerator Laboratory in 1974).

Page 66- A pen and ink drawing called "Goldwasser Grove". It was named for Edwin Goldwasser, former Deputy Director of Fermilab.

Page 69- Construction of Lab B around the 15 Foot Bubble Chamber and vacuum tank.

Page 70- A photograph of a page of the 15 Foot Bubble Chamber's Crew Chief logbook.

Page 73- The last operations crew to operate the 15 Foot Bubble Chamber. Pictured (from top to bottom) are Jerry Domoleczny, Bill Kellogg, Mike Mcgee, Jim Fagan, Bruce Lambin, Camilo Flores, Bill Hughes, Gene Desavouret, John Worster, Dan Burke, Bob Pucci, Dan Markley, Pat Healey, Chuck Mc Neal, Ivan Stauersboll.

Page 74- An impressionistic view of bubble events in a champagne glass. The photograph was taken by Olivia Gonzales.

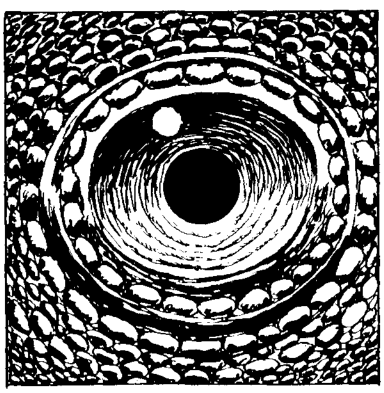
Page 77- Looking toward the roof inside the geodesic dome in Lab A.

Page 79- Constructing a model of the 15 Foot Bubble Chamber at 27 Winnebago in the Village.

Page 80- The front page of Fermilab's Village Crier, with a story highlighting the completion of the first run of the 15 Foot Bubble Chamber.

Page 120- A photograph of an Etruscan bronze mirror 4th century B.C., private collection. The photograph was taken by Olivia Gonzales.

Page 121- A photograph of a collage.



Acknowledgements

There were many people who contributed to the production of this book in addition to those who are represented here in writing. The process of transcribing the audio tape into a written document was done by Jody Federwitz, with later manuscript work being done by Kristen Ford. This was a long and arduous task for which I am very grateful. In addition to the comments made by each of the presenters, I would also like to thank Peter Garbincius, C. Thornton Murphy, Roy Rubinstein, Ken Stanfield and Ray Stefanski for their helpful suggestions in regard to technical matters. I am also very thankful for the help I received from Rick Fenner and Barb Kristen in regard to format and stylistic matters. Thanks also goes to Gordon Fraser, Editor of the CERN Courier, for the pictures he provided of bubble chambers at CERN and descriptions of each chamber. I would like to thank Olivia Gonzoles for her extreamly imaginative photographic contributions to the book. I would also like to acknowledge the tremendous amout of work done by Fermilab's Photography Department who produced all Fermilab related photographic contributions found in this book from the inception of the Laboratory until about one year ago. The final photographs were reduplicated by the recently formed Fermilab Visual Media Services Group.

Lastly, the most *obvious* contribution to the book was made by Angela Gonzales whose imaginative artistic style and deep appreciation of the history and development of science is evident in the overall layout of the book. Many of the visual images that she creates are statements revealing the depth of her conceptual understanding about particle physics, an understanding which is wonderfully woven throughout her original work.