The Illinois Physics Department

A Status Report
Prepared for the Nuclear Physics Alumni
by Peter Axel, in April 1974

Overview

Our physics department is quite healthy even though the steady growth we experienced since 1946 seems to have stopped several years ago when the job opportunities in Universities and Research Laboratories declined abruptly. We have grown into one of the largest departments, both in terms of staff size and of the annual production of physicists who have earned a Ph.D. Our department's high quality is widely recognized; surveys uniformly place us in the top 10. John Bardeen, with his two Nobel prizes in physics, is obviously our most famous staff member. We have many other well known physicists engaged in a variety of vigorous research programs.

Because it is impractical to summarize briefly the physics that is being done, I shall list only the broad areas of research. About half of the department's experimental effort is concentrated in solid state, low temperature, and atomic physics. Much of this work is done in the interdisciplinary Materials Research Laboratory (completed in 1965) which adjoins the "new" Physics Building (completed in 1963 on the northeast corner of Green and Goodwin streets). The other half of the experimental program is in subatomic physics, which is dominated by the Particle Physics program but which includes a modest nuclear physics effort. The experiments in Particle Physics are performed wherever beams of high energy particles are available. Our Particle Physics group is enjoying the advantages associated with being relatively close to the National Accelerator Laboratory in Batavia, near Chicago. Most of our smaller nuclear physics group is concentrating on a new electron accelerator which we are installing in the Physics Research Laboratory to replace the betatrons. More details about the nuclear physics efforts will be given below. Almost 1/3 of our present staff (i.e., about 20 physicists) are theorists who do not fit into narrow subfields. However, if I oversimplify I can call about one third particle theorists, one sixth nuclear theorists, one quarter astrophysicists, and the remaining quarter atomic, solid state, liquid crystal, and many-body theorists.

Some Statistics

The academic senior staff has grown to about 65. This number has been stable for about five years, but there have been a few new appointments per year mainly because of professors leaving for other jobs. The biggest change in student numbers has been in undergraduate physics majors. This number, which peaked at about 500 in 1967, declined steadily to about 250 in 1972. The number of graduate students peaked at 360 in 1965, remained between 330 and 300 until 1970, and is now about 260. There were 150 Ph.D. degrees granted between 1950 and 1960, 300 granted between 1960 and 1970, and the current rate is about 40 per year. The number of new graduate students has remained relatively constant at
about 90, although there was a dip to 63 in 1971. We can support most of these students with teaching assistantships because there are more students than ever taking introductory physics; about half of the 2000 take the three semester course which uses calculus.

The Departmental Administration

Since 1970, Ralph Simmons has been head of the Physics Department; Ralph got his Ph.D. here in 1957. There are two associate department heads, Jim Smith and Ernie Lyman, who assist Ralph. Gerry Almy was department head from 1964 to 1970, when he retired. Incidentally, Gerry Kruger retired at the same time. Fred Seitz had been head from 1957 to 1964, and he is now President of Rockefeller University. Wheeler Loomis was department head for 28 years until he retired in 1957. The Loomis' and the Almyns are still in town; Wheeler is quite ill.

If you would like more details about the history of our Physics Department, write requesting a copy of the 100 year history Gerry Almy prepared a few years ago.
The New Nuclear Accelerator Family

Since 1968 we have been developing a unique accelerator which will provide an essentially continuous electron beam. Such a beam has very important advantages over the usual pulsed beams, but has been impractical with conventional linacs because the large accelerating electric fields are accompanied by prohibitive wall losses. Our accelerator reduces these wall losses to of the order of 10 watts by using a superconducting linac; a liquid helium refrigerator is required to extract these watts of heat near 4°K. Our accelerator has another attractive and unusual feature: the electrons are recirculated through the linac, and gain the same energy on each traversal. A pair of identical uniform field, 180°, end-magnets are used to return the beam that emerges from the linac to the linac entrance. The different energy beams all travel down the linac axis in the same direction; each different energy follows a different return path, but the phases of the different returning beams are the same if the electrons are sufficiently relativistic. Our accelerator is therefore similar to a microtron whose magnet has been split in half and separated at the accelerating cavity. We originally called it a Superconducting Microtron, but the increased applications of superconducting magnets forced us to more cumbersome names, such as Microtron Using a Superconducting Linac (MUSL).

A prototype, MUSL-1, is now operating; we are doing nuclear physics experiments with its beam at the same time that we are improving its operation. The two betatrons and the cyclotron that were operating in 1968 are no longer used. MUSL-1 is a six traversal system which operates with a 1.3 GHz linac that provides an energy gain of only 3 Mev even though it is about 5 feet long. This linac was built at Illinois by machining niobium metal, and cleaning with only an acid etch; it deteriorated while it was being assembled and after a bad vacuum accident. However, it has been too valuable in the testing of the recirculation system and the resultant beam has been in too great demand for us to stop for reprocessing the linac. MUSL-1 is installed just south of where the 22 Mev betatron was located, on the other side of the big iron and concrete wall that was installed for special shielding. The nuclear experiments are being done in the areas which housed the 22 Mev betatron and the 75 Mev betatron.

For almost a year now, we have been first proposing and then planning for MUSL-2, which will be situated in the 300 Mev betatron "barn". The final arrangements were made last month between NSF and Stanford whereby Stanford's High Energy Physics Laboratory (HEPL) will make us a 6 meter superconducting linac and the cryostat in which it will be cooled. If these are shipped to us early next fall, as currently scheduled, we should have some beam and some recirculation by early in 1975. It is now our intention to operate MUSL-1 until the linac of MUSL-2 has been tested at Illinois. At that stage, we will probably move much of the recirculation hardware from MUSL-1 to MUSL-2. The nominal energy gain of the new linac is 18 Mev, but there has not been enough experience to be confident about what gain to expect. If the energy gain is as low as 10 Mev, we would probably install the six traversal system and use the 60 Mev beam. If the energy gain is higher, we will improve our end magnets so that we can exploit an energy near 100 Mev with a six traversal system.
Independent of the performance of the linac in MUSL-2, we hope soon to propose MUSL-3 which will include a larger number of beam traversals. We have a prejudice in favor of an accelerator such as was put forth in our original 1967 proposal: we want a 600 Mev continuous electron beam and can get it with a 20 traversal system and a 30 Mev linac. We are confident that a multitraversal system through a superconducting linac will be the best way to get high energy continuous electron beams because of the economies inherent in both its construction and operation. The major expense associated with such an accelerator may well be that associated with building, equipping, and using the experimental areas.

Other New Electron Accelerators

There have been several large electron accelerators that invested considerable money and effort to raise the duty cycle of electron beams from 0.1% to a few percent. The first was the 600 Mev linac at Saclay which has been operating for a few years. The 400 Mev linac that is being completed at M.I.T. planned a 2% duty cycle at maximum energy, and a 6% duty cycle at 200 Mev. A similar linac is scheduled to be built at Amsterdam. All of these accelerators are prepared to pay for the modest duty cycle by considerably increasing three costs: construction, replacement parts, and power.

Stanford and Illinois are the only two centers which have been working on or with superconducting electron linacs. Stanford pioneered this work, and is far ahead in testing experience and production facilities. HEPL had been planning a 1.3 GHz, 500 foot superconducting linac which would give an energy of 2 GeV. In 1967, Illinois announced its hope to produce a high energy electron beam by recirculating 20 times through a 30 Mev linac. When NSF provided funds for the "Construction of a Superconducting Linac" at Illinois in June, 1968, we began building a small linac to gain some experience with assembly, operation, and controls. We selected a length that would have gotten us to the energy range of 20 Mev if we could have achieved the 4 Mev/ft energy gradients implied by early HEPL tests on small test cavities.

The emphasis at both Stanford and Illinois changed in 1971 when it became clear that the gradients achievable were only about 1 Mev per foot. The decision to go ahead with building the 500 foot linac at Stanford was reversed, but HEPL has continued to develop superconducting linacs. HEPL has some projects which will use the electron beam, and are planning some intermediate energy physics proposals; however, at this time, no nuclear or particle physics experiments are definitely planned. At Illinois, the 1 Mev/ft gradient forced a decision to build a prototype recirculation system, in part, to provide a beam of usable energy to the experimental area. By the time the linac was completely assembled for the first time in March, 1972, the recirculation system was being assembled. By the summer of 1972, the injector was moved off the beam line and the 180° magnets were installed. The beam was recirculated through the linac in September, and by November, data were being obtained in the experimental area using the 6.5 Mev Beam. By February, 1973, a preliminary three traversal system had been
operated and a 9.6 Mev beam was being used in the experimental area. The six-traversal system required new vacuum chambers which were subsequently installed. By the end of the summer of 1973, the six traversal system was in place, and the three traversal 9.8 Mev beam through it has been available regularly in the experimental area since then. This three traversal beam is the one which is most used because of the particular experiments we are doing; experiments have also been done with the beam after 1,2,4, and 6 traversals.

The definite plans for obtaining an improved linac were made in the spring and summer of 1973 when it became clear that the niobium production facilities at HEPL might be unscheduled. We were encouraged by both NSF and the group at HEPL, and we proceeded with plans to install a 20 foot linac in the 300 Mev "barn" even though the final financial approval was not obtained from NSF until last month. A surplus Van de Graaff we obtained last summer was installed in the area, and will be the new improved injector. The last part of the 300 Mev betatron, the 275 ton yoke, is now being dismantled. New controls are being mounted in the old 300 Mev betatron control room. We expect the new accelerator to operate in 1975, and are hoping its energy will be near 100 Mev; however, we'll be pleased to work at 60 Mev if the particular linac we get has a low gradient.

The Transition

When we received NSF approval in June 1968 to start building a superconducting linac, there were seven senior staff concentrating on the three accelerators then operating at Illinois: Allen, Axel, Brussel, Hanson, Robinson, Sutton and Yavin. At that time it was clear that all three operating accelerators would be phased out rather quickly.

The 300 Mev betatron was the first to shut down; it produced its last X-rays in November, 1968. The last student to use its beam for experiments was Steve Klergan whose supervisor was Al Hanson. The previous Hanson student, John Staples, stayed on as a research associate and helped develop the superconducting cavity test program. Al Hanson took on full time duties of supervising the new accelerator, and has continued in that role. Clark Robinson has helped on different phases of the Microtron and Linac design, but most of Robinson's time is now spent at the Physics Building rather than at the Physics Research Laboratory.

The last experiments at the cyclotron were supervised by Brussel and Yavin who worked with the four students who were planning experiments in 1968: A. J. Buffa, J. Barengoltz, J. Opelka, and W. Givens. Mort Brussel was on a sabbatical leave at Orsay in 1968-69. The final cyclotron operation was completed in November 1969; Avivi Yavin left during that month to assume his professorship at Tel Aviv. The cyclotron was dismantled in 1970. Jim Allen helped some with the cyclotron during its last two years, but most of his effort then was devoted to the new accelerator. Our new project also obtained from former cyclotron staff the services of Bob Hoffswell, who has done much of the r.f. control design for our linac, and Curtis McGuire, who is an accelerator technician.
The 22 Mev betatron program was in a different category because the experiments and techniques developed to exploit its beam could be continued with the beam from the new accelerator. The use of the 22 Mev betatron ended in 1972 when it was clear that the new accelerator could provide a better beam. The last students to obtain thesis data with the betatron beam were Somnath Datta (with Allen), Dan Ganek (with Sutton), and Lloyd Young (with Axel). The yoke of the 22 Mev betatron is now being repainted so that it will be an attractive museum piece in the lobby of our physics building. Also exhibited are the dees of the world's second cyclotron; they are from the 2 Mev cyclotron which was built in 1936 by Gerry Kruger and Kenneth Green, who was then a graduate student.

From the time our new program began in 1968, we could have used more technical help and more money than we had. The three original Principal Investigators were Allen, Axel, and Hanson; only Hanson could devote full time. Jim Allen worked effectively in designing and installing the new injector, including a 300 keV electron gun. Most unfortunately, Jim Allen suffered a stroke in December, 1969. He was able to return to work, with the aid of a wheel chair, in May, 1970. He continued to regain his strength and resumed all his duties including a final Ph.D. student. But Jim decided to retire and move to Taos, New Mexico in June, 1973. I (Axel) have concentrated my efforts on budgets, proposals, and the experimental program. In the spring of 1971, I took a four month sabbatical with the Amaldi, Cortellesa, Campos-Venuti electron scattering group in Rome. Sutton deserted nuclear physics temporarily to learn about cleaning niobium surfaces; currently, he is concentrating on beam transport. We were fortunate to have the help of Darko Jammik, normally at Ljubljana, Yugoslavia who has led in the design of our recirculation system during his visits. The successful operation of the recirculation system, and our hopes for installing the new one rapidly rest on the ability of Lloyd Young who will be with us as a research assistant professor. We are fortunate in having experienced technicians and machinists who worked with the betatron programs. Jim Harlan divides his time between keeping the laboratory running, supervising the electronics shop, and helping with the accelerator installation. Frank Witt, who supervises the liquid helium production in the Physics Building, has spent much time helping solve our accelerator fabrication problems as well as those associated with cryogenics; he is now planning for the installation of our new C.T.I. 1400 refrigerator.

In the experimental area, we have eager and able graduate students. I have two, Mort Brussel has two, and Dave Sutton has one; all five are post-prelim and working on Ph.D. theses. We also have a new Assistant Professor, Larry Cardman, who comes from Yale via the National Bureau of Standards, and is preparing for an electron scattering program including coincidence measurements.
Summary

We are in the midst of an exciting transition. Our new accelerator is noteworthy, and we are confident that the increased experimental capability continuous electrons provide will result in significant experiments. We also feel that our students are getting particularly good training for three reasons: (1) the accelerator itself exposes them to new technologies, (2) they are using relatively sophisticated electronic and on-line computer techniques, and (3) their familiarity with the radiation environment near electron accelerators is rare in graduate physics schools at the same time that many hospitals and industrial processing plants are installing electron linacs. Our prospects for obtaining improved facilities seem good, despite the shortage of research funds. I would like to think that these prospects would be even better if I ended this report, and returned to the consideration of the interesting experiments we can do. Please let us know if you have questions or suggestions.

P. Axel

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