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"ATOM SMASHERS: FIFTY YEARS"
PREVIEW OF AN EXHIBIT ON THE HISTORY OF HIGH ENERGY ACCELERATORS

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In the latter part of this year an exhibit treating the historical development of high energy particle accelerators and detectors will open in Washington,DC, at the National Museum of History and Technology of the Smithsonian Institution. Filling 8000 square feet with historical hardware, the exhibit, which will continue for several years, is the product of a collaboration between ERDA and the Smithsonian, with essential contributions from several ERDA-funded accelerator laboratories.

"High energy particle accelerators--'atom smashers'--are today the largest, most sophisticated, and most costly artifacts of the scientific enterprise. They have surpassed the astronomical observatories, which for centuries--millenia--had dominated the scientific landscape. Fifty years ago such devices existed only in the minds of a few physicists, and twenty five years ago none were yet so large that they could not be brought under a single roof. Today the most powerful are miles across and hundreds of millions of dollars in cost. How have they grown to such a scale? That historical development is the subject of this exhibit." With these words the visitor, who has been drawn on by the atom-smashing jaws of the Oak Ridge 63-inch cyclotron, is introduced to a brief orienting slide sequence which juxtaposes dates and devices:

1930: Lawrence's first cyclotron (1 foot)
1940: Lawrence's last cyclotron (10 feet)
1950: Berkeley Bevatron (100 feet)
1960: Brookhaven AGS (1,000 feet)
1970: Fermilab synchrotron (10,000 feet)

With the leitmotif thus stated, verbally and visually, the exhibit proper begins forward left (Unit 1) with replicas, photographs, and manuscripts relating to radioactivity and nuclear physics before accelerators. Stress is placed upon the popular enthusiasm over radium early in the century as a precedent for the popular enthusiasm with atom smashers in the 1930's. Here and throughout the exhibit, descriptive labels, explanatory diagrams, and photographs, as well as various historical documents are placed directly before the visitor in narrow flat cases at railing height. (The recurrent rectangles in the floor plan.)

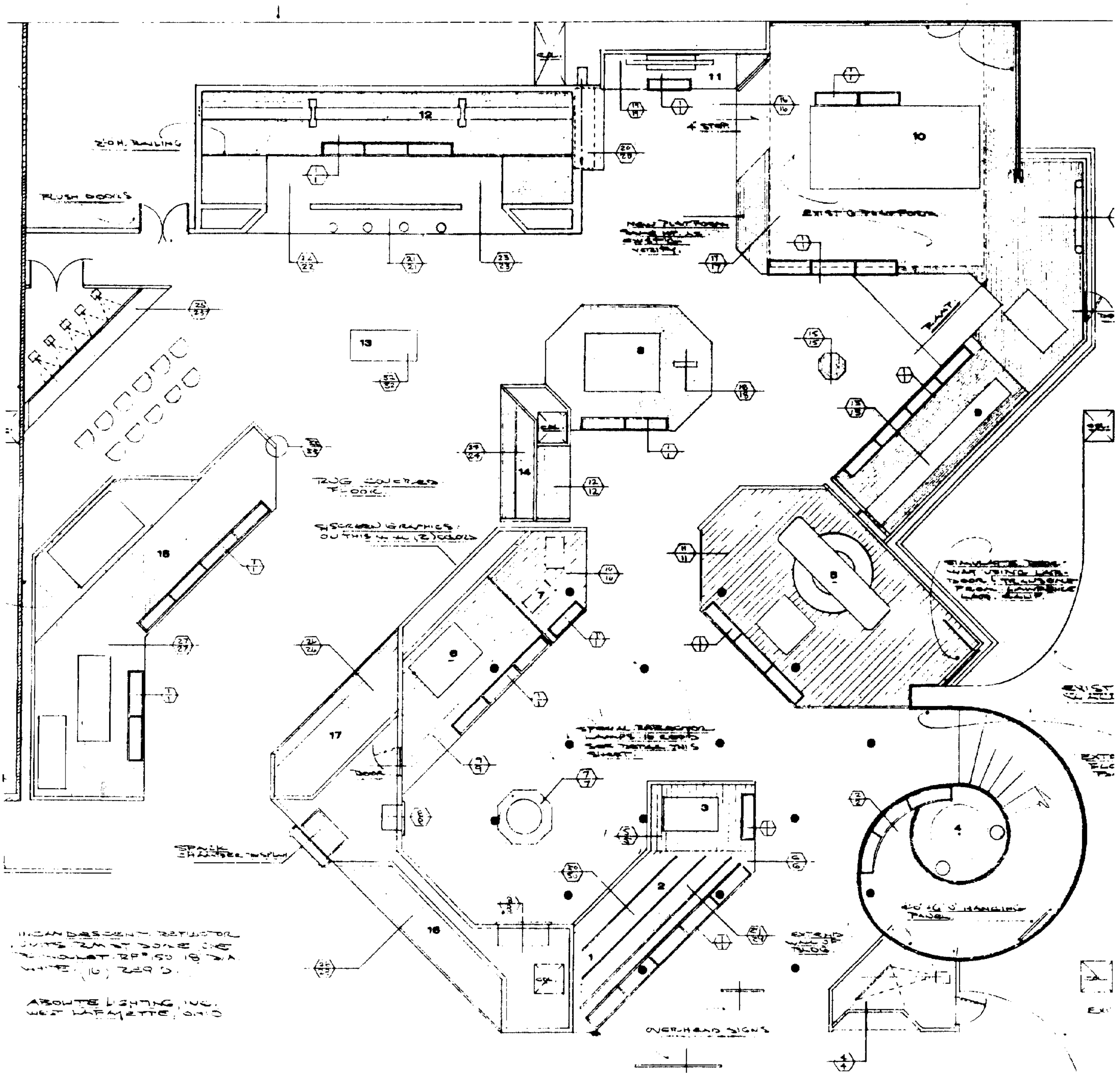
In the center of this tiered display the subject shifts to the earliest accelerator proposals and programs (Unit 2). The high voltage programs of Tuve and Breit at the Carnegie Institution of Washington, of Lauritsen at Caltech, and of Brasch and Lange in Germany are represented only by photographs, diagrams, Sunday supplement spreads, etc., but Van de Graaff's original 2-foot diameter demonstration model (1931) is exhibited. Under the rubric "premature proposals for circumventing high voltages" the earliest schemes for magnetic induction acceleration and linear resonance acceleration are presented. The outstanding items here are Rolf Wideröe's 1923 notebook depicting and describing his conception of a 'ray transformer,' and original sketches by E.T.S. Walton and Leo Szilard from 1928 of their concepts of a linear accelerator. We emphasize that these ideas occurred independently to a number of physicists in the 1920's, but proved unexpectedly difficult to develop. The "betatron," when, in 1940, Kerst finally got it to work, worked astonishingly well (to that development we will come in due course). But before World War II the linear accelerator was never more than a very qualified success.

At the end of this display devoted to preliminaries, a half turn left brings the visitor to face the first successful atom smasher : a full-size replica of the acceleration tube and observation cabin of Cockcroft and Walton's 1932 voltage-multiplier (Unit 3). The warrant for proceeding in this new direction--relatively low energy, but high intensity--was Gamow's theory of potential barrier penetration.

Facing about the visitor confronts the first Van de Graaff accelerator, that constructed at the Department of Terrestial Magnetism of the Carnegie Institution of Washington in 1932-33. (Unit 4. This is the one major item in the exhibit already on display.) Saddled in 1927 with the Tesla coil as a high voltage source, by 1929 Tuve was looking around for an affordable alternative. He was among the first to recognize the merit of Van de Graaff's idea, and so soon as Van de Graaff had established priority with a demonstration model, Tuve and his group were off and running. The visitor, descending the stairs, obtains a view of the business end of the accelerator. Here, along with later apparatus, are displayed original notebooks and drawings for the first quantitative proton-proton scattering experiments. The 2nd pre-War generation of Van de Graaffs, the pressure tank machines, are illustrated.

To the left of the DTM Van de Graaff, its massive magnet drawing the visitor from afar, is a reconstruction of the Berkeley 27-inch cyclotron as it appeared circa 1936 in the old radiation laboratory. On the right, one of the original "Rad Lab" doors stands open. The original 70-ton magnet remains in Berkeley before the Lawrence Hall of Science. But on the table in front of this convincing replica is an original vacuum chamber. One of the last, and the only surviving, it sits as if withdrawn from the magnet for servicing, just as in many early photographs. In the case in front of the diarama are several laboratory notebooks and pocket diaries kept by Lawrence and Livingston in the period from the first unambiguous success of the cyclotron principle--a replica of this 4-inch diameter vacuum chamber is included--to the construction of the 27-inch. Also displayed, inter alia, is a log book of "HMS Cyclotron, E.O. Lawrence Master" from the period represented by the diarama, 1935/36, and a postcard from Gamow with a coat of arms for E.O. Lawrence, atom smasher.

The story of Lawrence and cyclotrons at Berkeley continues across the way with the control console of the 60-inch cyclotron as focal object (Unit 6). (In an alcove off to its left are, for amusement and instruction, three operating devices, the most noteworthy being a mechanical analog of the cyclotron.) This control console, a finished piece of furniture in the then modern style, bespeaks the transformation in the way accelerators were designed and built at Berkeley in the late 1930's and in this country generally after World War II. (The 60-inch cyclotron



Floor plan. The topical units of the exhibit are numbered in roughly chronological sequence.

1. Before accelerators: radioactivity and nuclear nuclear physics, 1896-1932.
2. Beginnings: the earliest proposals for accelerators and the programs of the late 1920's.
3. The first successful atom-smasher: Cockcroft and Walton's voltage multiplier, 1931-32.
4. The Van de Graaff: Tuve's 2-meter generator at the Carnegie Institution of Washington, 1933.
5. The cyclotron: Lawrence, The "Rad Lab," and the 27-inch machine, 1929-36.
6. Sixty inches and thrice sixty: the culmination of prewar cyclotron construction, 1938-40.
7. The first betatrons: Kerst's, 1940, and Germany's, 1944.
8. The proton linac: Alvarez' 30-MeV linear accelerator, 1945-47.
9. The electron linac: development at Stanford from the 1930's to the 1960's.
10. The electron synchrotron:phase stability and McMillan's 330 MeV machine, 1945-49.
11. The proton synchrotron: Brookhaven, the "Cosmotron," and strong focusing, 1948-60.
12. Fermilab: the main ring of the world's most energetic accelerator.
13. Ion sources for accelerators: historical development.
14. Particle counters: early ionization, scintillation, and Čerenkov detectors.
15. Bubble chambers: from Glaser's earliest to the Brookhaven 80-inch, 1952-1964.
16. Current particle detectors: "towards an all-electronic bubble chamber."
17. Current accelerator developments: superconductivity and colliding beams.

was completed in 1939; this control console, its second, was built in 1945.) Lawrence's personal prominence, further elevated by the award of a Nobel Prize late in 1939, together with his fervent promotion of medical applications, made it possible for him to build the 60-inch cyclotron, and then to fund the "ultimate" cyclotron, the 184-inch.

Juxtaposed to this projected mammoth is its lilliputian contemporary (Unit 7), Kerst's first betatron, which, as the attestations in his laboratory notebook prove, operated successfully for the first time on July 15, 1940. Displayed alongside Kerst's is Germany's first, built in 1944--during the War--at the Siemens-Reiniger Werke in Erlangen.

Advancing between betatron and 27-inch cyclotron, the visitor finds on his left, as interlude and bridge between the pre-War and post-War periods a tiered display of graphic materials representing atom smashers as they appeared in the contemporary "public mind's eye." The materials are selected primarily to manifest, and hopefully rekindle, the enthusiasm for atom smashers which existed among the general public in the 1930's and 1940's. From a speaker overhead issue Arthur Robert's cyclotron songs of this vintage.

Out of the hiatus enforced by the World War emerged new concepts, and out of the experience of war time projects emerged a new scale, for high energy accelerators, which now advanced beyond atom-smashing into the field of elementary particle physics.

The first representative of post-War accelerators to be encountered is a piece--the first sixth--of the Berkeley 30 MeV proton linac. This, like the electron linac being developed simultaneously across the San Francisco bay, depended essentially on the concepts and technology of radar. Each was conceived as but the initial stage of a billion volt machine. The 24 surplus radar oscillators lined up on both sides of the 40-foot tank were an insignificant fraction of the nearly 800 that Alvarez had secured to power his projected machine. But by the time this first section, after some discouraging setbacks, operated successfully late in 1947 it was clear that this was not the optimal way to get protons up to a BeV. A number of documents, including letters by General Groves and by Alvarez to his parents, show the circumstances of funding and building the accelerator, while photographs show the subsequent development of proton and heavy ion linacs.

Advancing to his right the visitor comes upon not a single accelerator but an integrated exhibit (Unit 9) treating thirty years of electron linac development at Stanford, from Hansen's and the Varian's pre-War experiments on the interaction of cavity resonators and electron beams through the building of the two-mile accelerator. Pre-War developments are represented by a Hansen "Rhumbatron" and notebooks kept by Russell Varian recording the origination of the concept of the "klystron."

The concept of a traveling wave electron linac, a wave guide in which the phase velocity keeps pace with the electron's velocity, occurred during the War to a number of people involved with microwaves. The first to this conception was evidently David H. Sloan. The post-War work along these lines of Hansen, his collaborators, and successors is represented by two-foot sections, both intact and cut-away, of the Mark I (1947) and Mark III (1950) electron linear accelerators, together with a Mark III klystron. Each of these objects is cantilevered forward from the first 9 feet of an 18-foot length of support girder from the SLAC 2-mile linac. The last 10 feet of the girder are surmounted by wave guide and all hardware pertaining to a length of the accelerator. Among the supporting and explanatory materials is Pres. Eisenhower's reading copy of his speech announcing his administration's decision to back the $100 million project, autographed and dedicated to his Science Advisor, James Killian.

Standing upright behind the visitor is a SLAC klystron sectioned longitudinally to reveal its structure. And on the left, suspended by its trunions from the ceiling, is the 6 MeV electron linac developed in the early 1950's by Stanford accelerator physicists and radiologists--the first medical linac in this country.

To the left, mounted on the wall, is the 2-meter diameter vacuum chamber of the Berkeley 330 MeV electron synchrotron (Unit 10). Turning about and retracing a few steps one stands before the machine itself. A direct application of the principle of phase stability conceived by McMillan at Los Alamos in the closing months of the War, this accelerator was constructed under his direction with Manhattan District funds in the three years following. Under the circumstances, the conflation in the public mind of atom smashers with atom bombs is not so difficult to understand.

Photoproduction of π^0mesons in 1949 by Steinberger, Panofsky and Steller exemplifies experimentation with this accelerator; the synchrotron log book and the experimentalists' notebook are displayed. The visitor can walk entirely around the synchrotron, mounting in the rear upon the platforms which gave access to the r-f oscillator, vacuum pumps, etc.

Descending from the electron synchrotron, one stands before an 8-foot by 8-foot magnet lamina of Brookhaven's 3 BeV cosmotron (Unit 11), initiated in 1948 along with Berkeley's 6 BeV Bevatron. Although Oliphant had begun two years earlier on his 1 BeV Birmingham machine, in the spring of 1952 the Cosmotron became the first operative proton synchrotron. In Brookhaven as in Berkeley, the accelerator builders' dream had been of a 10 BeV machine. But it was the Russians--unknown to the West--who were realizing it.

Turning left away from the Cosmotron magnet the visitor faces a large vertical exhibit case devoted to the general subject of particle focusing by magnetic fields. First the laborious methods of magnet design and testing in the 1940's are stressed, with the display of a set of field gradient search coils used for Cosmotron model measurements. Via the concept of field gradients the viewer is thus led to the problem of particle focusing, and the historical circumstances of the discovery and application of strong focusing by alternating gradients. At the bottom of the case, running along its length, is an optical analog of particle focusing by quadrupole lenses. Above it historical artifacts are displayed.

The discovery of strong focusing at Brookhaven is represented by Ernest Courant's notebook, begun in August 1952, on the concept of an alternating gradient synchrotron. The first demonstration of the principle was by Alvarez's group at Berkeley in October, and the electrostatic quadrupole lenses which they then installed in the drift tubes of their linac are exhibited, both entire and sectioned. Beside them is one pair of electrostatic lenses of the 50-foot diameter electron analog that Brookhaven built in order to examine questions of beam dynamics, and especially the problem of phase transition, before proceeding to the AGS. The first machine actually to employ magnetic alternating gradient fields was the BeV electron synchrotron then under construction at Cornell. Short stacks of these large "n" pole piece laminae are mounted to represent a cross section thru poles and vacuum chamber.

Alternating gradient focusing had been conceived a few years earlier in Greece by Nicolas Christofilos. Christofilos was a citizen of the United States, and as such entitled to file for a US patent. Displayed is the attested and sealed oath which he swore to this effect in the American Embassy in Athens.

The route from Brookhaven to Batavia, historically long and complex, is in this exhibit unfortunately covered in one leap. Walking around the corner, the visitor is before the entrance to a mock-up of a 35 foot length of the Fermilab tunnel (Unit 12), in which a definite spot in the ring is replicated in full detail with authentic hardware--bending and focusing magnets, busses and piping, pumps and valves, etc.

Although still some distance from the end of the exhibit, the visitor, on emerging from the tunnel is very nearly at the end of our continuous narrative: "atom smashers" as they have evolved in the last fifty years. The final installment is in a capacious case a dozen paces ahead. Advancing directly to this exhibit of "Current Developments" (Unit 17), one finds on the left objects relating to superconductivity, and on the right storage rings and colliding beams. The development of high field superconductivity is represented by early tiny solenoids of niobium from Hulm (1955) and niobium-tin from Kunzler (1961), and the solenoid for the Argonne-Carnegie Mellon 10-inch liquid helium bubble chamber, the first of such a size. Brookhaven and Fermilab have each contributed a specimen of the superconducting magnets they have been developing for handling higher energy beams. Here too is rf superconductivity represented by a section of the Stanford University superconducting linac.

The right hand side of this case is given over to storage rings and colliding beams. While recognizing the early proposals and productive machines in the United States, the opportunity is taken here to emphasize that in the last two decades Western Europe has joined us at the forefront of accelerator development. Thus at the rear is a replica of the "AdA" vacuum chamber (1961), the first electron-positron storage ring, and before it an authentic intersection chamber from the CERN proton-proton Intersecting Storage Rings. These are augmented by various documents, running from Touschek's "AdA" notebook to current proposals for storage rings in lieu of accelerators of continental scale.

There remains yet another quarter of the exhibit, now to be touched upon very briefly. Apart from one small case on ion sources for accelerators (Unit 13), this portion of the exhibit deals with particle detectors. There is a case of particle counters (Unit 14), with gas ionization detectors on the left--including one of Walter Müller's original Geiger-Müller tubes and notebooks, and other apparatus from the 1930's and 40's. On the right are photoelectric detectors (including Bell's first anthracence scintillator and Hofstadter's first sodium iodide scintillator, as well as photomultiplier tubes, etc.). There is a much larger case on "Current Developments in Particle Detection" (Unit 16). This, alongside an operating spark chamber responding to cosmic rays, displays various types of chambers, hodoscopes, etc., including Charpak's 1968 prototype multiwire proportional chamber and drift chamber. Touching on the multi-mode, multi-particle, detector-spectrometers, the exhibit ends with ψ/J discoveries.

The largest and historically richest of these detector exhibits is that on the bubble chamber itself (Unit 15). Introduced by a replica of Wilson's cloud chamber, and touching upon nuclear emulsions, it runs from Glaser's earliest experimental bulbs through his practical ether and xenon chambers, and then traces liquid hydrogen chambers from Hildebrand's first, though the Berkeley 4-inch and 15-inch, to the Brookhaven 80-inch, the discovery of the Ω^-, and Gell-Mann's Nobel. This problem of getting the physics out is symbolized by a "Franckenstein," indeed the first (1957).

In a corner between bubble chambers and the Fermilab tunnel is a multiprojector slide theater. Here, as and when we are able to prepare material, or it may be prepared for us by accelerator laboratories, slide shows supplementing and complementing the exhibit will be presented.

(In presentation this paper was illustrated by 180 slides.)