

Physicists and Education

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It is timely once again to discuss education and its necessary improvement, but here I just sketch the involvement of physicists in improving not only science education but elementary learning, which presumably has the greatest of benefits for acquiring skills, and also for socialization. I attended elementary and junior high schools in Cleveland, OH, and then junior and senior high in Cleveland Heights, received a B.S. in Physics in 1947 from what is now Case Western Reserve University in Cleveland, and in 1949 a Ph.D. in Physics with Enrico Fermi at the University of Chicago, where I taught and did research for three years before joining IBM at a small laboratory in Manhattan in December, 1952. Since then I have had an exciting career in science, technology, and public affairs.

Here I will indicate what some physicists, including myself, have been up to these past 60 years or so. The involvement of physicists in school education stems from the National Defense Education Act, signed September 2, 1958, by President Dwight D. Eisenhower. With the NDEA, the federal government became a major player in education at all levels, as a result of the shock of the Soviet launch of the first artificial earth satellite, Sputnik, on October 4, 1957.

My first involvement in education, aside from in my own, was in the 1950s with the Physical Sciences Study Committee-- PSSC-- created in large part by MIT physicist Jerrold Zacharias, and an outstanding team from Harvard, MIT, and elsewhere. PSSC was focused on school courses in science, to replace the existing curriculum, and to provide not only a sound basis in science, but also by teaching and study aids, motivate

students to learn. Recognized from the beginning was the difficulty of such a curriculum change, which had to be taught by the same teachers who had not only not been teaching in this way but had not been educated with this approach. Those of you who have had the experience of a PSSC course may recall the fantastic pictures from the team and the high standards associated not only with the course materials but with the emphasis on teacher training.



Of the same genre is the iconic film, *"Powers of Ten,"* by MIT physicist Phil Morrison, and architect/designers Ray and Charles Eames.



My own earlier experience with Jerrold Zacharias began just after I joined IBM in December 1952, when he and Jerome Wiesner, later to become President Kennedy's Science Advisor, asked IBM to provide a “leading engineer or physicist” for a year's service on the LAMP LIGHT study of extending the air defense of North America to the sea lines of approach of Soviet nuclear-armed bombers. I managed to negotiate that assignment down to three days per week (Tuesday-Thursday), which I spent in the Boston area on the interesting study, while my wife coped with two young sons and a small apartment in Riverdale. Jerrold Zacharias, instigator and seasoned participant in

MIT national security-related summer studies, enjoined us, “Don't get it right; get it written,” apt advice for group accomplishment.

Edward M. (Ed) Purcell said later about Zacharias, “... *one of the many times in my life when I had been enlisted under the banner of Jerrold Zacharias. In most of those times I was glad afterwards that I had, and this was certainly the case in PSSC.*”

Following the introduction of the PSSC courses, with all the difficulties associated with local control of public schooling in the United States, the amorphous group went on to create the Berkeley undergraduate physics course, of which Purcell, on sabbatical at Berkeley from his regular position at Harvard, wrote the outstanding Volume 2 on Electricity and Magnetism. More about Purcell later, who received the 1952 Nobel prize in Physics for his work on nuclear magnetic resonance—the basis of magnetic resonance imaging (MRI) and much else.

When I was working with the PSSC group, I got to know not only the physicists but also psychologists such as Jerome Bruner, and, soon, polymaths such as Pat Suppes of Stanford University, who was a founder of computer-aided instruction—CAI—and in particular the Stanford University *Education Program for Gifted Youth*. Particularly in elementary education, it seemed to me that what was needed was evaluation of different approaches to teaching, of different students, and teachers. There is such a tremendous range among students, from the visually centered to the analytic, that it is unlikely that a single approach would be best for all, and a more flexible tailoring of instruction and

participation would likely be best. For instance, some individuals are more comfortable with an abstract algebraic approach in mathematics, while others have a visual flair that gives them an advantage in plane geometry. In general, our local school districts are not so much lacking in experimentation as in the ability to evaluate experimental programs of others.

Evaluation of an approach to early teaching is far more difficult than even a good test at the end of the term to determine retention of facts or even skills. Most important is to influence the attitude of the student, to instill a passion for learning and doing, and self-confidence that the child can learn successfully. This might be tested some years later, but it is very difficult to tease apart the contributions of various teachers and courses.

Addressing later a feeling that most children in the United States were now surrounded not so much by the natural world of sky and stars and brooks and vegetation, but by artifacts and technology, Edward E. David of Bell Telephone Laboratories (later to be President Nixon's Science Advisor) initiated a program to provide a high school or junior college course, *The Man-Made World*, on which I worked. John G. Truxal of Brooklyn Poly was later the key person in the program, when Ed David was occupied in Washington.

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Man-Made World had its own problems, because there was no course in the high school curriculum for it to replace, and students are too busy to handle an additional course, no

matter how valuable. Moreover, there was the feeling that because of their earlier experience in school, a lot of students were already lost to learning and particularly to science technology, engineering, and math (STEM)-- to use the current term. Helping them in high school and junior college is much too late.

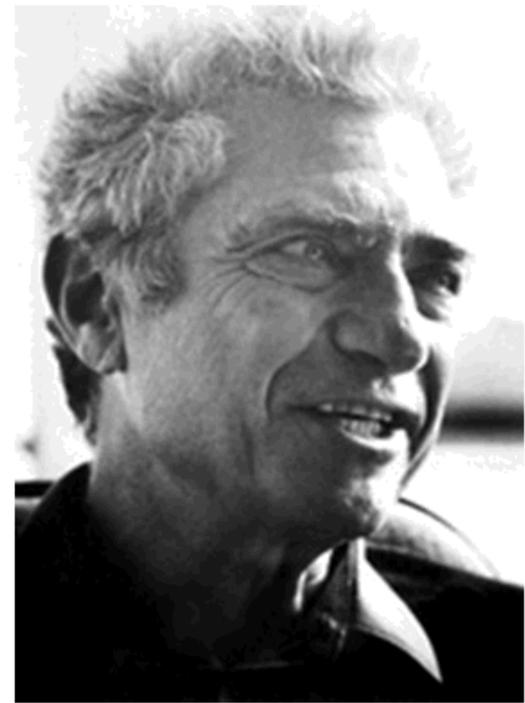
More recently, physicist Leon Lederman of Columbia University and then Director of Fermilab, helped to advance the Illinois Science and Math Academy (ISMA) a publicly funded residential 3-yr school, and then moved to introduce hands-on science into the elementary schools in Chicago, including the education of hundreds of teachers in this new curriculum that was the product of work at Stanford and elsewhere. Lederman is a prominent particle physicist



Leon M. Lederman



Melvin Schwartz



Jack Steinberger

The Nobel Prize in Physics 1988 was awarded jointly to Leon M. Lederman, Melvin Schwartz and Jack Steinberger *"for the neutrino beam method and the*

with whom I was good friends on the Columbia University faculty, and with whom I quite unexpectedly worked intensively for several years beginning January 1957, as attested by this front-page article from the New York Times of January 16, 1957, dealing with a revolution in fundamental physics—in our case the decay of the pi-meson (“pion”, pronounced “pie-on” to a mu meson (“muon,” pronounced “mew-on”), and in turn to an electron: $\pi \rightarrow \mu \rightarrow e$ in 20 billionths of a second and 2 millionths of a second, respectively.

by this 1/17/57
**Basic Concept in Physics
Is Reported Upset in Tests**

*Conservation of Parity Law in Nuclear
Theory Challenged by Scientists at
Columbia and Princeton Institute*

By HAROLD M. SCHMECK Jr.

Experiments shattering a fundamental concept of nuclear physics were reported yesterday by Columbia University.

The concept, called the "principle of conservation of parity,"

*The text of Columbia report
will be found on Page 24.*

has been accepted for thirty years. It must now be discarded, according to the Columbia scientists.

The idea that destroyed this principle originated with two theoretical physicists, Dr. Tsung Dao Lee of Columbia and Dr. Chen Ning Yang of the Institute for Advanced Study at Princeton, N. J. They suggested certain definitive experiments in papers on the subject: "Is Parity Conserved in Weak Interactions?"

The generally accepted belief, which had been a part of nuclear physics since 1925, was that parity should be conserved.

Two sets of experiments sug-

Dr. Lee and Dr. Yang suggested that perhaps it would be necessary to give up the principle of parity to gain an explanation of the sub-atomic interactions. They found that certain experiments dealing with particles better known than the K mesons could resolve the puzzle.

One set of experiments, done in a low temperature physics laboratory of the Bureau of Standards, showed that disintegrating nuclei of radioactive Cobalt 60 exhibited a specific "handedness," or spin in a given

entists.

The principle of parity states that two sets of phenomena, one of which is an exact mirror of the other, behave in an identical fashion except for the mirror image effect.

The principle might be explained this way:

Assume that one motion picture camera is photographing a given set of actions and that another camera simultaneously is photographing the same set of actions as reflected in a mirror.

If the two films are later screened, a viewer would have no way, according to the principle of parity, of telling which of the two was the mirror image. The recently completed experiments indicate that there is a way of determining which of the two images is the mirror image.

In communicating with people in an intelligent civilization on another world, the Columbia report explained, it would be impossible, with the principle of parity in effect, to tell whether or not they and we meant the same thing by right-handed or left-handed. This could be true and still the basic physical laws in both worlds would behave exactly alike. The recent experiments indicate that this is not the case for some weak interactions of sub-atomic particles.

Two sets of experiments suggested by the two theorists showed that this parity was not conserved. A team of four Columbia physicists in collaboration with a member of the Institute for Advanced Study and a team at the National Bureau of Standards carried out the work.

The meeting that released the results of the experiments was held at 2 P. M. yesterday in Columbia's Pupin Physics Laboratories at 119th Street and Broadway. The chairman of the meeting was Dr. I. I. Rabi, Columbia's Nobel Prize-winning physicist.

"In a certain sense," Dr. Rabi commented on the development, "a rather complete theoretical structure has been shattered at the base and we are not sure how the pieces will be put together."

Physicists present at the meeting indicated that it might take a long time to evolve a new concept on the basis of the recently achieved results. One scientist said that nuclear physics, in a sense, had been battering for years at a closed door only to find that it is not a door at all but a likeness of a door painted on the wall. Now science is at least in a position to hunt for the true door again, he observed.

K Mesons Led to Doubts

The Columbia theorists were led to doubt the principle of parity because, during the last few years, phenomena had been described in high energy physics that could not be explained by existing theories. This was particularly true of the patterns by which certain sub-atomic particles called K mesons decayed. Nobody was able to formulate a theory to account for both of the two methods of decay that they followed.

"handedness," or spin in a given direction.

The other set of experiments dealt with the decay patterns of pi mesons. These are sub-atomic particles that are better understood than the K mesons. The pi mesons are believed to be largely responsible for the force that holds atomic nuclei together.

The disintegration pattern of the pi meson also showed a definite "handedness."

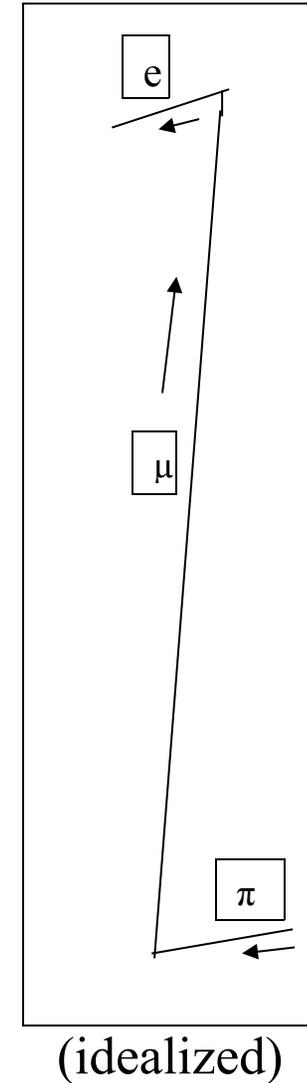
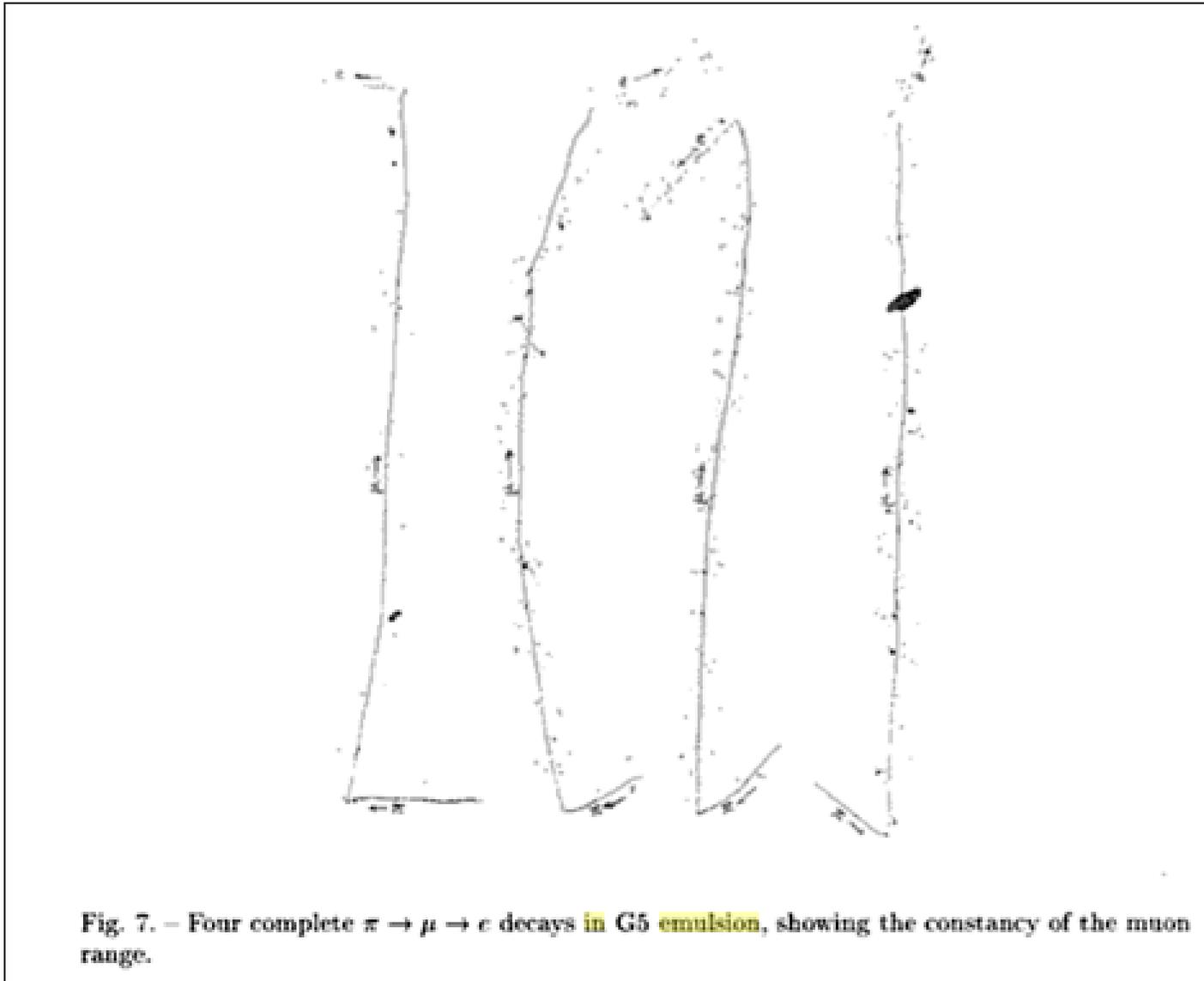
Scientists contributing to the work in addition to Dr. Lee and Dr. Yang are listed by Columbia as Dr. Ernest Ambler, Bureau of Standards; Dr. Richard L. Gavin of Columbia's Watson Scientific Laboratory; D. D. Hoppes, physicist of the Bureau of Standards; Associate Prof. Leon M. Lederman of Columbia and Associate Prof. Chien Shiung Wu of Columbia.

Three of the scientists, Dr. Lee, Dr. Yang and Dr. Wu, were born in China. Dr. Wu is considered the world's leading woman physicist. Dr. Lee is 30 years old, Dr. Yang, 34. All three are married and have children.

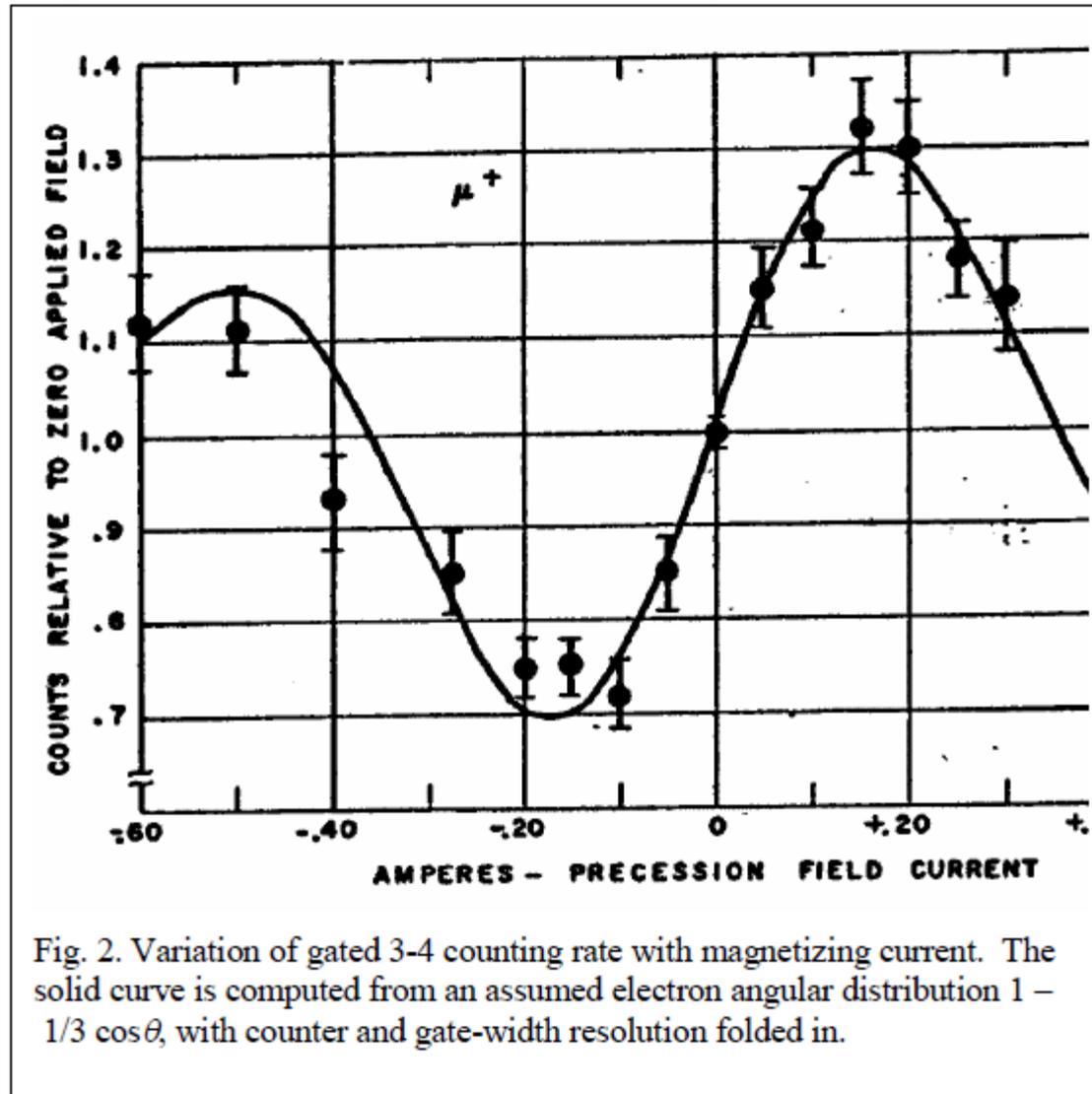
Dr. Ambler, 33, was born in Bradford, England, and attended Oxford, where he earned the B. A., M. A. and Ph. D. degrees. Dr. Garwin, 28, a native of Cleveland, received his B. S. at Case Institute of Technology, and his M. S. and Ph. D. at the University of Chicago. Mr. Hoppes, also 28, was born in Liberty, Ind., and received the B. S. at Purdue and the M. S. at Catholic University. He is married and has two children.

Professor Lederman, born in New York in 1922, received the B. S. at City College, and the A. M. and the Ph. D. in physics at Columbia. He is married and the father of two children.

In 1956, groups had begun to look for asymmetry in the decay of the muon in thick photographic emulsion, evidenced by more electrons forward (or backward) from the stopped muon, relative to its path just before stopping after almost a millimeter of film.

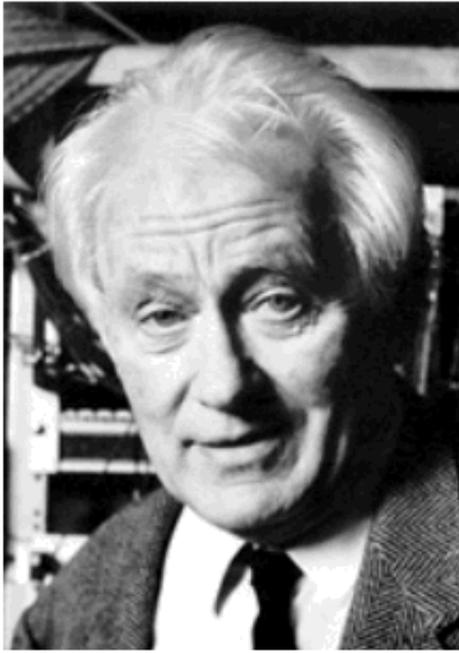


But with the faint electron track it is easier to detect the sharp angle of a backward $\mu \rightarrow e$ decay (“scanning bias”) than of a forward decay, and no definitive results were obtained until after our 4-day experiment at the Nevis (Irvington) lab of Columbia University, which provided this spectacular curve from the decay of muons from the cyclotron,



We worked furiously to exploit this new tool, in competition with physicists the world over. So easy! But later experiments took longer. Lederman spent a sabbatical year at the European Particle Physics Laboratory in Geneva, Switzerland—CERN, beginning September, 1958. One of the young members of a group, assembled there by Lederman, was Georges Charpak, who had just received his Ph.D. in Paris on the subject of gas discharges used for nuclear particle detection, at which he was ultimately very innovative and successful.

I then led this so-called “CERN muon g-2 experiment” from September, 1959, and after its conclusion in 1962 Charpak said that he was not going to participate in experimental physics anymore because no experiment could live up to the thrill and perfection of what we had done. Instead, he was going to improve his particle detectors for use in biology and medicine, which he did, but in addition they have dominated particle physics in enormous sizes, resolution, and sophistication these past decades.

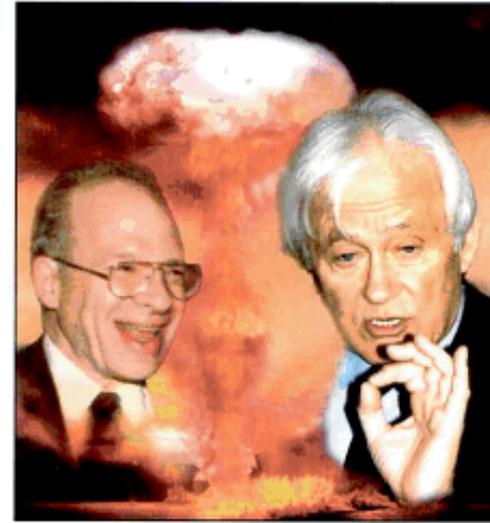


Georges Charpak

The Nobel Prize in Physics 1992 was awarded To Georges Charpak “*for his invention and development of particle detectors, in particular the multiwire proportional chamber*”.

GEORGES CHARPAK
RICHARD L. GARWIN

FEUX FOLLETS et
CHAMPIGNONS NUCLÉAIRES



Dessins de Sempé



Luis W. Alvarez, University of California at Berkeley, Nobel Prize in Physics in 1968, had perfected the “bubble chamber” invented by Donald Glaser, with whom I went to college at Case Western Reserve University in Cleveland, to operate not with propane or other relatively conventional liquefied gas, but with liquid hydrogen at only 20 degrees (Celsius) above absolute zero. Glaser had conceived the bubble chamber over beers with his students. Hydrogen had the advantage that as a target for particle beams or cosmic rays, the only nuclei present were protons, thus simplifying analysis and producing a larger number of elementary reactions with protons than was the case with the hydrocarbon bubble chambers. Alvarez, who was far from timid or lacking in self confidence, predicted that the bubble chamber within a decade, with its stunning images of particle tracks, would have replaced essentially all electronic counters in particle physics experiments.

Fortunately, Charpak rescued us from that dismal possibility, because the bubble chamber had very long “dead time” so that it would have been able to capture only a tiny fraction of the nuclear interactions that can be revealed by Charpak's particle-counting approaches.

After receiving his Nobel Prize in 1992, Charpak continued to perfect particle detectors, but he had the freedom and the status to engage in other important activities, such as judging candidates for “Marianne,” the symbol of France. He, too, turned to elementary

education, vowing to introduce in all of France the “hands-on science” that Lederman had himself transplanted to Chicago. It would not have gone well in France to indicate that this was a translation and transplant of an American program, but Charpak freely volunteered to confidants that this was the case.

Public education in France has the combined advantage and difficulty that it is centrally directed. On any day, all of the first-grade classes in French public schools are on the same page of the syllabus, and the teachers have a uniform “formation”-- education. So if the central education system-- minister and staff-- could be persuaded of the superiority of a new approach, it might be deployed quite rapidly throughout all of France.

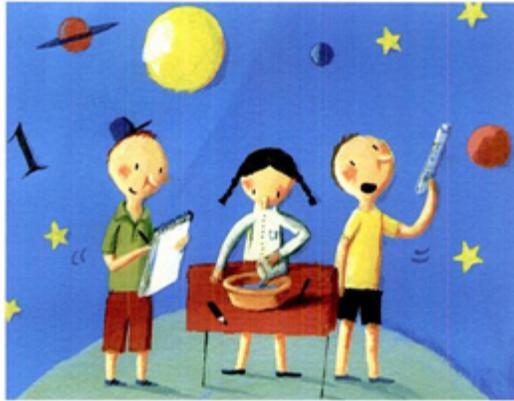
But first, as an experimental physicist, Charpak had to be assured that it really would transplant. So he led initially a small effort to provide the educational materials suitable for French kids and French language, and to obtain French manufacturers of the teaching aids. The students liked the approach, and some teachers were able to handle it, so in fact there has been a rapid expansion in France of hands-on science learning called “*La Main à la Pâte*”-- “Hands in the dough.”

Charpak died in September, 2010, and at a memorial session for him in March 2011 at the Academy des Sciences in Paris, there were two talks on his work on *La Main à la Pâte*-- one on its introduction in France, and the other on its spread to Europe and to some of the rest of the world.

G. Charpak, P. Léna, Y. Quéré

L'Enfant et la Science

L'aventure de La main à la pâte



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Associate Director for Science
of the Office of Science and
Technology Policy—OSTP.

I have been only peripherally connected, especially in recent decades, with educational reform, which, however, is a priority of the Obama White House, with Nobel physicist Carl Wieman of OSTP a pioneer in demonstrating benefits of interactive instruction —“clicker questions” and 3-student consensus groups.

I did, myself, have great fun over the years with really three simultaneous careers-- one in fundamental scientific research as typified by my work at CERN and by the New York

Times 1957 account of our fundamental parity experiment; work in technology and management at IBM, where I helped introduce the laser printer to the industry, as well as being in at the beginning of the integrated circuit silicon revolution; and a third in technology and security for the U.S. government-- dealing with nuclear weapons, military technology, reconnaissance satellites, air traffic control, and the like.

When T.D. Lee and C.N. Yang began their theoretical analysis of the validity of the law of conservation of parity, Lee spoke with a renowned woman physics colleague at Columbia, Chien-Shiung Wu, who identified cobalt-60 as perhaps the best experimental candidate. This experiment on Co-60-- a common industrial source for intense radiation-- required cooling tiny samples of the radioactive material to thousandths of a degree above absolute zero. Madame Wu, a great expert in beta decay at Columbia University and a close friend and colleague of T.D. Lee, asked me in September 1956 whether I would collaborate on doing that experiment, because she had learned that I was building an innovative cooler at our small IBM laboratory at Columbia University. But I was fully involved at that time leading a 100-person IBM Task Force on developing technology to build a superconducting computer, and I told her that she could do no better than to work with the expert team at the U.S. National Bureau of Standards in Washington, DC, despite the burden of commuting. Here is a picture of Prof. Chien-Shiung Wu at that time.



and another,



Miss Wu's work with the team at the National Bureau of Standards in Washington saw definite results from their experiment on December 27, 1956. Leon Lederman and I didn't think how properly to do the parity experiment on the $\pi \rightarrow \mu \rightarrow e$ decay until 8 p.m. Friday night, January 4, 1957, when Leon and I met at the Nevis cyclotron of Columbia University. By 6 a.m. Tuesday morning, January 8, we had the precession curve and the paper essentially written, with only about 12 hours of data taking-- because the cyclotron was down for maintenance from early Saturday morning until Monday evening. That was really enough excitement for a lifetime.

The IBM work on superconducting computers was very interesting too. In addition to their thesis work for a Ph.D. at Columbia University, Physics graduate students at our

laboratory were paid to help out with the general research in the lab, in this case that on planar superconducting computer elements.

Here is an example – one of my graduate students, Myriam Sarachik, now Distinguished Professor of Physics at City University and a former President of the American Physical Society. She is also a member of the U.S. National Academy of Sciences. And in her working togs at the Watson Lab,



The work on the thin-film cryotron-based superconducting computer was overtaken by the enormous flood of research and improvement on silicon-based semiconductor integrated circuits, but in the mid-1960s an IBM researcher, Juri Matisoo, invented an approach based on “Josephson Junctions,” which was much faster than anything that could be achieved with cryotrons. Although no significant commercialization of

superconducting computers has been achieved, they are under assessment, even this year, as candidates for the highest performance computers-- on the order of a billion times the performance of your enormously capable home personal computer-- itself packing more computing power and memory than was used to design the most modern nuclear weapon in the U.S. stockpile.

I hope that you don't mind my having talked about some of my own exciting days, in addition to introducing some of my wonderful colleagues and their work as physicists on education. They were there with President Dwight D. Eisenhower when he needed them after Sputnik, and, almost all academics, they knew how much society and security depend on an educated public.

“Women hold up half the sky,” and also the professions of medicine and law. Less so in physics, mathematics, and engineering, but there is progress. When Enrico Fermi asked me in 1951 about the “shell structure” of nuclei, “Is there any evidence of spin-orbit coupling?” I did not rise to the occasion; a week later he made the same suggestion to Maria Goeppert-Mayer, and the rest is history:



Maria Goeppert Mayer,
Nobel Prize 1963



Felix Bloch



Edward Mills Purcell

The Nobel Prize in Physics 1952 was awarded jointly to Felix Bloch and Edward Mills Purcell "for their development of new methods for nuclear magnetic precision measurements and discoveries in connection therewith"

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By the way, Ed Purcell, whom we met earlier, with Edwin Land (inventor of Polaroid light-polarizing film and also of instant photography) and Frank Bello (Fortune Magazine and Scientific American) wrote a "*Space Primer*," published by the White House just after Sputnik, at the time that Purcell and Land had key roles in the very secret exploitation of space and the stratosphere for national reconnaissance:

*

The "Purcell Panel," headed by E. M. Purcell, included A. F. Donovan, E. G. Fubini, R. L. Garwin, E. H. Land, D. P. Ling, A. C. Lundahl, J. G. Baker, and H. C. Yutzy--perhaps the most distinguished group of authorities on reconnaissance, space, and photography ever to be collected in one study group. Many of the

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Education and Technology

The nigh-ubiquitous Web and the ingenuity and drive of a few individuals or groups is bringing us new approaches to learning, such as the “Khan Academy” of Salman Khan, www.khanacademy.org, delivering via YouTube 7-minute modules covering hundreds of topics for high-school and college students, and for anyone who wants to learn.

Renowned professors such as William H. Press (*Numerical Recipes*) are innovating, too, Press with his series,



by Bill Press

Opinionated
Lessons
in Statistics

#1 Let's talk about probability

Professor William H. Press, Department of Computer Science, the University of Texas at Austin

And Stanford University, led by its electrical engineer president John L. Hennessy is firmly embracing the web for learning at all levels. Some “classes” enroll 100,000 students, and “crowd sourcing” provides most of the answers to questions not resolved by the brief lecture modules.

In an interview published May, 2012¹, Hennessy states, *“But online education is going to happen; it’s not going to wipe everything else out, but it is going to happen. We have to embrace it.”*

Zealots may have had the same view in the 1970s, but now you can see it for yourself, even in New York City, where 250 schools are in the Innovation Zone (iZone) associated with the League of Innovative Schools, which is a major initiative of the independent Digital Promise organization chartered by Congress during the George W. Bush administration and now up and running in the Obama administration. Digital Promise’s Board is appointed by Secretary of Education Arne Duncan, recommended in part by Members of Congress of both parties. One of its board members is Mark Dean, IBM VP and Fellow (1995) and a leader in the IBM technical community.



¹ *IEEE Spectrum*, May 2012, pp. 28-32, http://spectrum.ieee.org/geek-life/profiles/john-l-hennessy-risk-taker/0_06/05/2012_