

PEP talk

At the critical point, any transient local reordering becomes a long range effect which spreads across the whole sample.

These critical effects resulting from local reorderings would be expected to show up in a number of ways. Instead of falling off exponentially, Yukawa-style, as in isolated nuclei, the nuclear pion field is expected to spread out as the condensation point is approached. In addition, the pion field is expected to oscillate, so that all kinds of new effects could be expected. (Conditions for the formation of pion condensates are more favourable in neutron stars for example, but evidence, and conclusions, are necessarily more indirect.)

The present attitude seems to be not whether pion condensation will be found, but when. Already some phenomena are seen which could be due to enhancements of the pion field in actual nuclei. For example the properties of the 15.1 MeV level of carbon-12 cannot easily be explained in conventional terms and could be indicative of the onset of a nuclear critical point (see December 1979 issue, page 411). However more work is required to pin down these new effects.

(For more current ideas on possible new nuclear behaviour, see the report on the recent Heavy Ion Workshop at Darmstadt, page 396.)

The newly operating PEP electron-positron storage ring, built by the Berkeley and Stanford Laboratories, was dedicated on 5 September. At the banquet, Fermilab director Leon Lederman was as usual in great form — here are some extracts from his speech.

I have been concerned to understand why I was chosen for this great honour — to speak at such a historic occasion. Is it that I am known as a dedicated scientist? I've been involved in the dedication (in one way or another) of a large number of accelerators. Somehow these accelerators overcome this handicap and manage to do great science anyway. This is however the first machine I've been involved in dedicating in which I have no experiment. I think this could be a bad omen so I brought along a modest proposal...

Seriously I decided, after reflecting on my thirty-five years in physics,

to take three aspects of this standard career and make three solemn and related points.

Could I have been invited because of my teaching career? I probably hold some kind of record in particle physics with fifty-two or so Ph. D.s, most of whose theses I have personally rewritten. It isn't easy. You sit down at midnight after a hard day in the lab with a nicely typed, bound thesis of your best student (call him Fauntleroy Rabinowitz to protect living persons). This student is good! Harvard College, A+ whiz in the lab, hardware / software, etc.... You should read his software — it is absolutely lyrical. We thought of him as the Emily Dickinson of machine assembly language. He could do Feynman diagrams with one hand and with the other hand, be on the telephone, arguing down the price of phototubes. He worked like a dog sixteen hours a day for three years,



The SLAC landscape, with the linac coming in from the top left. The service road for the PEP electron-positron ring and the buildings at the intersection areas can be clearly seen at the bottom. Not visible is Leon Lederman giving an entertaining speech at the PEP dedication banquet on 5 September.

(Photo Joe Faust)

Leon Lederman giving one of a series of Saturday morning talks on particle physics to high school students. The ten-week series takes the students through relativity, quantum mechanics, accelerators and detectors, quarks, cosmology and even spin-offs. Many Fermilab physicists are participating in the programme.

(Photo Fermilab)



making apparatus work, curing background problems, critically analysing data... and his thesis is 90 per cent THEORY! 'In 1935 Yukawa discovered the pion...' Then there is his command of language: listen to this pinnacle in the saga of mixed metaphors: 'This is a field of physics, so virginal that no human eyeball has ever set foot in it.'

Another one of my great students, Irving Tweed-Harris, came from an old British family that invented the hyphen, much used in physics today. Tweed-Harris illustrates failures in other educational systems. After the standard British period of general education, Tweed-Harris began specializing in the pion-nucleon problem at the age of nine!

In the easy informality of the graduate student lounge at Columbia they used to call him Mr. Tweed-Harris, Sir. He was just not the sort you could call Irving. His thesis also

began with stuff about Yukawa.

Of all the informal and formal courses I have taught — the most difficult one by far was the 'Physics for Poets'. The Columbia Lib Arts students were bright, and sceptical. I looked at them as future newspaper editors, lawyers, company executives, Congressmen — in all aspects of industry and government. I had them for three hours a week for a year — what an opportunity and what a responsibility! Could my physics course influence their way of thought? Could I diffuse an appreciation of the scientific attitude deep enough to affect their personality, their judgement and taste? It was difficult and I really don't know how successful. Richard Feynman is better at it. Who can forget his method of explaining velocity as a ratio of infinitesimals?

Cop: Lady, you were speeding. I clocked you at 60 miles an hour.

Motorist: That's ridiculous. I've only been driving for fifteen minutes!

Now when we realize that I and perhaps as many as twenty or so of my equivalents can reach a few thousand students a year — we see the magnitude of the problem faced by science in what may be an issue as large as the survival of democracy in the technological age. How can we maintain democracy if the citizens are scientifically illiterate? In general the college science requirement doesn't work and the problem is compounded by the illiteracy of the teachers in the private and secondary schools. And yet there are large efforts going on and much concern. For all I know there are special committees with the responsibility to do something.

The problem is not newly perceived. There have been alarms in ever-increasing intensity since World War II. The possibilities for improvement are vast. We have compulsory education. We have private and secondary schools. We have an impressive college population and we have the TV. We have succeeded in educating people to accept inoculations, drink fluorinated water, jog and quit smoking. Do we have the clout to install a long range and insidious programme of fostering public understanding of science?

Of course we have to be clear ourselves as to what are the key issues: Are there limits to science capabilities? How does one distinguish between good and bad technology? Can there be such a thing as a dumb Ph. D. in physics?

It seems obvious to me that the responsibility for finding a solution is in the University, both for its students and for the wider community. Install a four year science requirement — sponsor prime time TV

science spectacles, ... I don't know but do something!

The next topic relates to my experience and involvement in the content of particle physics. I think that most of the spouses, non-physicist types who have some relationship to a particle physicist, must catch some of the intense excitement that characterizes the field today. It is fair to say that we are now in the midst of one of these rare revolutionary periods — that come once every twenty to thirty years. If we recognize Relativity and Quantum Theory as two of the great intellectual revolutions, we are in the midst of a third one now. It doesn't yet have an agreed-upon name — Constituent Theory, Grand Unification...

The trouble with this period is that, as with all previous revolutions, the theorists get much too much credit. I don't want to discuss Einstein and Dirac because they aren't here to defend themselves but when you think of how long it took the current heroes to come up with quarks and Quantum Chromodynamics, after almost rubbing the data up their noses, and then to know that future generations will only know about a few theorists!

We were finding new particles like mad from 1950 to 1964 before theorists finally came up with quarks as the underlying scheme. We discovered the second neutrino in 1962 and it should have been totally obvious that we needed a charmed quark but it took theoreticians several years to see it. And I could go on.

What gets me is that they are so over-confident. Theoretical over-confidence is probably the worst problem we face. Shortage of funding comes next.

But still it is an exhilarating time and I'd like to tell you one fascinating story to illustrate this.



Leon Lederman: 'theorists get too much credit'. Here he is (looking for theorists?) at a buffalo roast at Fermilab.

(Photo Fermilab)

If I tried to characterize the results of the past two decades' probing of inner space, using accelerator-microscopes of ever increasing power, it is that — as we zoomed down and down past the atom, into the nucleus, focus sharp! Zoom into the nuclear proton — at first, a fuzzy cloud — then, three sharp but rapidly moving objects... and down... and suddenly we were making quantitative measurements of the motions of these quarks, we were detecting evidence of the glue that binds them together, and finding that, in the cloud-like environment of the quark there were traces of a new and unsuspected family. And then, when we look up from our accelerator-microscope, across the room our astrophysics colleagues look away from their telescopes. We talk and we find that we are looking at similar things.

They tell us that they hang on all

developments in particle physics with great interest, that there wouldn't be any sensible progress if they didn't know about neutrinos and about quarks and about the quark forces. They are intensely interested in whether the proton — long thought to be perfectly stable — does in fact have a measurable half-life. In the past they needed to know about nuclear forces and beta decay to account for the sun's heat and the properties of neutron stars. But the story goes both ways — the cosmological evolutions of the Universe has phases which would make even Fermi's mythical globe-encircling accelerator look feeble. The early Universe (someone said) is an accelerator laboratory with a totally unconstrained budget. Some of this is contained in Steve Weinberg's book, 'The First Three Minutes.' (It sells like hot cakes because many people think it is a book on sex!)

Lederman paddling his own canoe (with the help of George Luste).

(Photo Fermilab)

At Fermilab where, in the next three or four years, we hope to explore an energy domain which is truly original, beyond any confident prediction, we are planning a long series of talks and symposia on the hints we can get from both cosmology and cosmic rays. Because the interaction is so fruitful, we are campaigning for the NASA Space Telescope Institute to be located at Fermilab so that astrophysicists and particle physicists can literally drink coffee and discuss.

One specific issue that excites us has to do with the neutrino.

This little fellow has provided a steady diet of surprises ever since Pauli proposed it in 1930. Enrico Fermi named it and used it in the first mathematical treatment of radioactive decay. His properties as developed both experimentally and theoretically were bizarre.

We now know that there are three different varieties or families of neutrinos. Until recently most physicists believed (and many still do) that these were all massless, precisely zero mass and therefore always moving with the velocity of light.

Recently there has been an accumulation of evidence, none of it convincing, which has raised the question of how 'zero' are the masses. These questions have profound philosophical implication — which tends to make physicists more critical of the data.

The new evidence is quite comfortably received by some theorists who are trying to unify the weak, electromagnetic and strong forces. In special cases of these new theories (modestly entitled Grand Unification), neutrinos do have small masses and could well 'oscillate' between themselves. But what is the evidence? To me, the more fascinating data come from our astrophysics friends who tell us that they



can measure the mass of a galaxy by the properties of hydrogen atoms that orbit the galaxy. The result of this weighing of the galaxy comes out much greater than the mass obtained by counting stars and by well-tested rules associating mass with luminosity. Where is the residual mass? Dark stars? Black holes? These possibilities are made remote by the fact that the same data shows a continuation of mass density far away from the boundary of the visible galaxy. Then, why only dark stars there and no bright ones? One plausible hypothesis is that the unseen mass is vested in neutrinos which fill the galactic environment. An elementary calculation can explain the data if the neutrino weighs more than 20 electronvolts (25 000 times lighter than the electron). Implications are profound for theories of the evolution of our Universe.

Neutrinos with a rest mass of 20 eV would dominate the total mass of the Universe. If the mass of the neutrino were heavy enough, this would imply a gravitational mass density in the Universe sufficient to slow down the present expansion. This expansion, which began at the birth of the universe (Big Bang), would eventually come to a halt. Pulled by the gravitational attraction of the neutrinos (and more conventional stuff), all the matter in the

Universe would rush together to form again the hot singularity, heralding a new cycle and so on ad infinitum.

Various pieces of laboratory data from reactors, from accelerators and from our own sun suggest or tend to support the notion that the neutrinos do indeed have a rest mass, but each one is flawed and the issue is surely still open. New experiments are now proposed — at reactors, at the large accelerators of Fermilab, Brookhaven and CERN — to settle this issue. The stakes are high in human comprehension of an enormous range of concepts: the basic laws of physics and especially the Grand Unification of Forces, the properties of particles of incredibly small dimensions, the mechanism of the sun's energy source, the significance of the Big Bang and the future evolution of the Universe. These are the kinds of mind-boggling issues that the PEP experimenters will deal with in the next years.

I come now to my most recent activity — the administrator or Director of Fermilab. Now I get into problems of community; we are part of a nested set of communities. Like the sequence of molecules to atoms to nuclei to quarks we are part of a world community of highly educated citizens with a special responsibility towards the preservation of the cultural heritage and the social well-

being of this planet. We are a community, high energy physics, complete with all the internal dissension and competition that is so normal in families. But on the occasion of this solemn pause for the dedication of PEP we stand together in mutual respect, love and awe at the heritage of our science.

And basic research does (in spite of the grey areas and the difficulties of rigorous definition) define a community — again both culturally and socially. The mathematician, however pure, is influenced by and contributes to the developments in molecular biology. Cosmology and particle physics have never been closer; plasma physics supports fusion, physics of the upper atmosphere and astrophysics. And altogether, we are constructing what Viki Weisskopf calls '...one of the great creations of contemporary culture: a vast intellectual structure which, on the basis of a few constants, provides a framework for a unified description of the natural world from the fiery beginning to the existence of life on our planet.'

When you march forth to defend basic research you find there is no attack! Everyone loves basic research. So what are the difficulties? Basic research or many of the basic research disciplines are in deep trouble. Let me take high energy physics where all major accelerator Laboratories are in serious difficulty and discuss it from only one direction — that is the flow of young physicists into the field. We all know that graduate student enrolment in physics is dramatically down. It is not unusual to see two physics professors — colleagues and friends for thirty years — coming to blows over the sponsoring of one mediocre graduate student.

Look at the numbers of high energy physicists. Back in 1965,

there were, in the US, 1100 experimentalists and about the same number in Western Europe. Today in the US there are still 1100 but there are 2000 in Europe. This comes from a region with the same GNP as the US and the same population base.

Now I worry enormously about those missing 900 experimental particle physicists. Where are they? I'm not reassured if you tell me they went to medical school — not that I'm against medical schools, I'd love to see so many doctors graduated that it would not be unusual to have your doorbell ring and a neatly dressed young man carrying a little black bag ask if anyone is sick inside!

I worry because one of them, turned off by a sour high school teacher, forewarned about job prospects by a sincere college advisor, discouraged by public attitudes or his perceptions of them — this one guy puts on a backpack and camps out and the world has lost a Newton or a Maxwell or a Panofsky or a Jonas Salk or an Edison or a Steinmetz — someone who could just save the world.

To achieve an intellectual breakthrough requires lots of delicately balanced conditions but the one essential ingredient is the young mind and it is obvious that the wider the base, the better the chance. One loss could be disastrous if we had to wait another twenty or thirty years. We don't have the time!

The books I have read teach me that societies vanished totally or slept for centuries because of errors of judgement — by failures of the culture to adapt to the problems facing the society.

A defensible perception of the problem facing us is that it is largely technological. It has to do with four billion people and a scale of living which cannot be set far lower than

that which we now enjoy. We, the affluent 20 per cent, have already made significant inroads on the natural world which we inherited from geological ages. It has to do with minerals, laid down over geological history and now depleted. It has to do with natural geochemical cycles being accelerated. Atmospheric trace contaminants can alter climate. How do we extend a reasonable standard of nutrition, energy supply, health, transportation, shelter to the other three billion people in the face of these issues? It seems to me that this is the central question, first for science and technology, then surely for statesmen. This is why I worry so much about the missing 900 physicists.

PEP comes on with some unusual handicaps. It is of course competing with PETRA at DESY. It is late and it will take all the ingenuity and imagination that this great Lab, with its great traditions, can muster to catch up and show the world that US physics is strong and that the large funds vested here are well spent. In this respect this Lab and this Community owe a tremendous debt to John Rees, the man on the front lines who led PEP construction, and to Burt Richter, who not only was a seminal figure but had time to come and help me in my first shaky year at Fermilab.

We are a community and we depend upon one another's successes. Good luck!