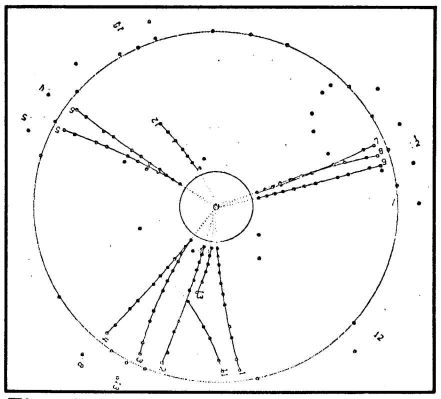
Physics With Strings Attached

If gluons exist, they perform a crucial function. And now we have the evidence that they do exist.

BY DIETRICK E. THOMSEN



The three-jet arrangement of tracks characteristic of hard-gluon production.

On August 24 a group of physicists announced to the 1979 International Symposium on Lepton and Photon Interactions at High Energies that they had found evidence of the existence of a particle called the gluon (SN: 9/1/79, p. 151). The first reports were tentative. The evidence was necessarily indirect. What followed was a phenomenon that could be described as evangelistic. Other people praised the result, and various physicists, as they talked it up, wound up building their own and each other's confidence in the event and in its importance for physics.

(It has also been said that this event was hyped in the media for political purposes. A more judicious assessment would be that the physicists took advantage of a response that was generated by the inner dynamics of the news media, see box.)

But as the television cameras ground and the wire service tickers clicked, the question that was going around the corridors of the Fermi National Accelerator Laboratory, where the symposium was held, was: "Is the gluon real?" The question does not necessarily have to do with doubts of the experiment, although there are those. The camp meeting atmosphere by no means converted everybody. The question goes to the role of gluons in physics and to the nature and intentions of the theoretical physics that conceived them. By the definition of that theory gluons are not directly observable. What the experiments measure — there are four of them, all attached to the PETRA colliding beam facility of the DESY laboratory in Hamburg — are secondary phenomena caused by gluons. Even assuming the correctness of the measurements and conceding that gluons are responsible, the question of the reality of gluons is still posed.

"Gluons are as real as virtual photons." Thus spake E. Thomas Nash of Fermilab. That could be called a phenomenological view except that it contains, perhaps wittingly, a touch of a catch. The word "real" has a certain technical meaning in this context. A real particle is one that is directly detectable in the physicist's particle detection equipment (or would be if the equipment were fast enough). A virtual particle is by definition not detectable. It spends its entire existence under the protection of the Heisenberg Uncertainty Principle.

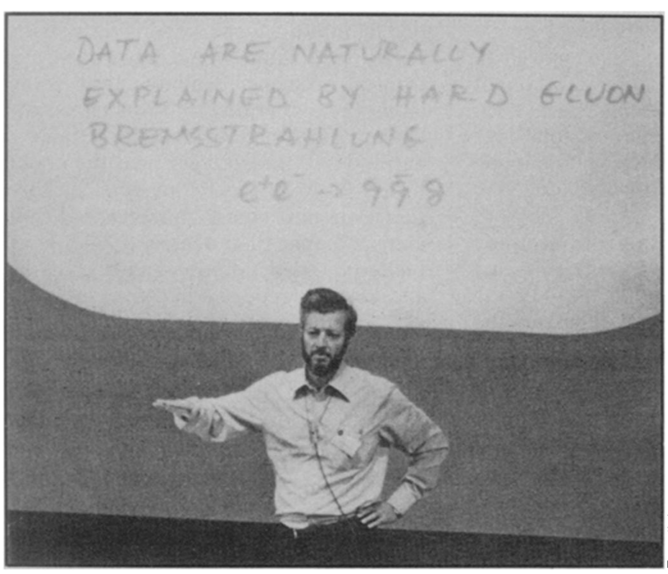
According to the uncertainty principle there is a reciprocal uncertainty in the measurement of the energy carried by a particle and the time of the measurement: The more closely the energy is known, the more uncertain the time and vice versa. If all the energy a given photon is allowed to have is taken as the maximum possible uncertainty in energy, that will establish a minimum uncertainty of time in any attempt to detect the photon's existence. If the particle's whole existence lasts less than that minimum, nobody can be certain whether it was there or not. Such a fleeting existence gets the technical term "virtual."

Virtual photons may seem to be almost nothing — real photons are usually not very much — but they have important physical consequences. A virtual photon may not be "real," but it can be defined. Its characteristics can be discussed. It can be shown to be the proximate cause of many kinds of observable phenomena. It is often the intermediate state in time between one set of observable phenomena and another. It is just that, in fact, in the electron-positron collisions that are the basis of the experiments involved in the gluon question: Electron and positron (which are very real and observable) collide and annihilate each other. The annihilation produces one (sometimes two) virtual photons, which then turn themselves into something and then something else that finally becomes observable again.

If virtual photons are not "real," they can certainly claim some kind of actuality. The terminology does not call them "unreal"; it seems to imply that something can be less than fully real and still exist. Gluons are said to be as real as virtual photons, but for a somewhat different reason. Gluons are supposed to be the embodiment of the force that holds quarks together. That is, gluons bind together two quarks, or three quarks as the case may be, to make up the overwhelming majority of the observable particles. They are sometimes visualized as strings with quarks at their ends.

But quarks and gluons are themselves never observable. *By definition of the theory* they are bound to remain inside the structures they compose and can never come free to be observed by themselves. One of the analogies used is that they are caught in a "bag" defined by the particle they are part of. What the experiments measure as evidence of the existence of gluons is streams of observable particles that reproduce the theoretically expected pattern of the decay of two quarks and a gluon, which themselves spent their whole existence inside the bag.

Assuming the correctness of the experiments, gluons can be granted as much as is granted to virtual photons, but physi-



Fermilab

DESY's *Günter Wolf could hardly make his opinion plainer.*

cists are far from unanimous that it matters. Some will say that it does. After all, gluons are central to the whole structure. Others, not a few, say simply, ho-hum.

"To hell with phenomena. Who needs the boring old man from Königsberg." The quote is not from a physicist. It's from a Russian Orthodox priest, and it comes from another discussion entirely, but the slogan seems apt for printing on tee shirts. It could help distinguish the teams. Murray Gell-Mann, one of the people who introduced the idea of the quark, has often said that he doesn't believe they exist. For the success of the theory, they don't need to exist.

What matters is the pattern, the symmetry under the observable phenomena. The individual phenomena themselves are no longer very important, and it no longer matters whether certain predictions of the theory result in phenomena. The phenomena of particle physics reveal the existence of complicated symmetries in the structure of nature. The patterns of these symmetries, the relationships and transformations among the elements of the pattern are the content of the theory. If the symmetry that seems to be manifest predicts quarks (or gluons), they need not really exist. They can simply be convenient ways of thinking and calculating transformations among elements of the pattern. That is about how Gell-Mann intended them. The existence of quarks, or of neutrons or protons for that matter, is less important than that God should think in SU(3), SU(6), 0(5), 0(10) or whatever (those being the mathematical names for some of the symmetry groups) as He creates.

There is a school of physicists that would like quarks and gluons to be physical objects. They like to think of ordered structures of matter, of things within things, of protons within an atomic nucleus, quarks within protons, etc. It is, however, a minority view, as Haim Harari of the Weizmann Institute in Rehovot, Israel, admits. Yet it has eloquent spokesmen. M. Veltman suggests that if there had been symmetrists, as he calls them, in the days when the structure of the hydrogen atom was first studied, they would have noted that the pattern of its energy levels fits the symmetry group called 0(4). That would have been the end of progress, says Veltman. No one would have worried about the nucleus and the electron and the forces that bind them. No one would have gone on to the study of the atomic nucleus.

Maybe. The example is meant to make symmetrists look ridiculous. That was a different stage in the development of physics and a different level of the organization of matter. The symmetrist argument is that the present stage is qualitatively different from any that went before. After all, no one ever talked of a virtual uranium nucleus. □

Hypergluons: The discovery of a media particle

What is truth? The question was asked by Pontius Pilate in days of old, and it is asked by physicists today—though not about the same subjects. Are gluons really there? Do they do what they're advertised to do? Is SU(6) God's favorite symmetry group?

In any aspect of existence it's a difficult question to settle, but, remembering that Pilate asked his question in reference to news reports, let us transpose the question one key downward in the scale of pomposity and ask: What is news?

Gluons may or may not be truth. As long as they are part of the discussion, they are news to anyone interested in physics. Are they news to the general media in the United States?

When the physicists at the 1979 International Symposium on Lepton and Photon Interactions at High Energies decided that they indeed had gluons, they decided to test the question by informing the press. The result was about what you might have expected from the press's previous interest in physics. The press conference, held by two theorists, was sparsely attended, and that seemed to be that.

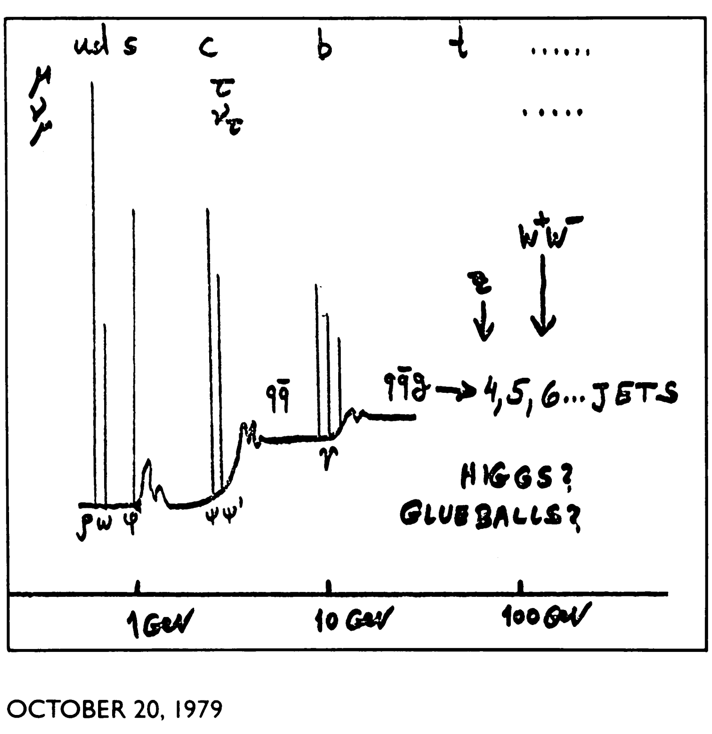
But a reporter for the Chicago Tribune had been persuaded to write an account, and the editors put it on page one. We were flabbergasted when we saw it. Somewhere in the labyrinth at the mouth of the Chicago River was a (city? managing?) editor who thought physics was as important as baseball. Hosanna to the son of Colonel McCormick.

But why precisely this story? There had been four or five stories of equal import to the development of unified physics in the last couple of years that were all nearly completely ignored by newspapers. Perhaps, as our publisher suggests, the name "gluon" and the jokes a writer can make with it was the deciding factor.

But there was no time to philosophize. The firestorm started. The press works on a herd instinct. If a newspaper puts a story on page one, its competitors must have the story there too. If the wire services pick up the story, newspapers all over will want it whether they have any idea what it's about or not. That's what happened here. From Alberta to Florida they filled two days calling Fermilab. As a result of the interest a second press conference was called, which was attended by more physicists, more press and television cameras.

Here the opportunity was deliberately taken to air American physicists' grievances over the financial strangury and bureaucratic obstruction they feel they face. They have a point. As the gluon story itself exemplifies, Europe is going great guns at these things. The continent seems to have overcome the bureaucratic and diplomatic problems that were cramping its efforts a few years ago. Meanwhile the United States has come down with a case of terminal bureaucratic paralysis and a governmental aphasia in which the right brain doesn't know what the left brain is doing.

All this needs to be aired. The gluon story is a natural vehicle. It didn't have to be hyped. It was there. All that was necessary was to get someone's attention. That was accomplished.



As physics goes up in energy, new particles and new quark flavors appear. Quark flavors are listed across the top, particle names along the curve. The quark-antiquark-gluon combination first appears on the farthest present extension of the curve.