SLAC BEAM LINE

"There are therefore Agents in Nature able to make the Particles of Bodies stick together by very strong Attractions. And it is the Business of experimental Philosophy to find them out." -- Isaac Newton, Opticks (1704)

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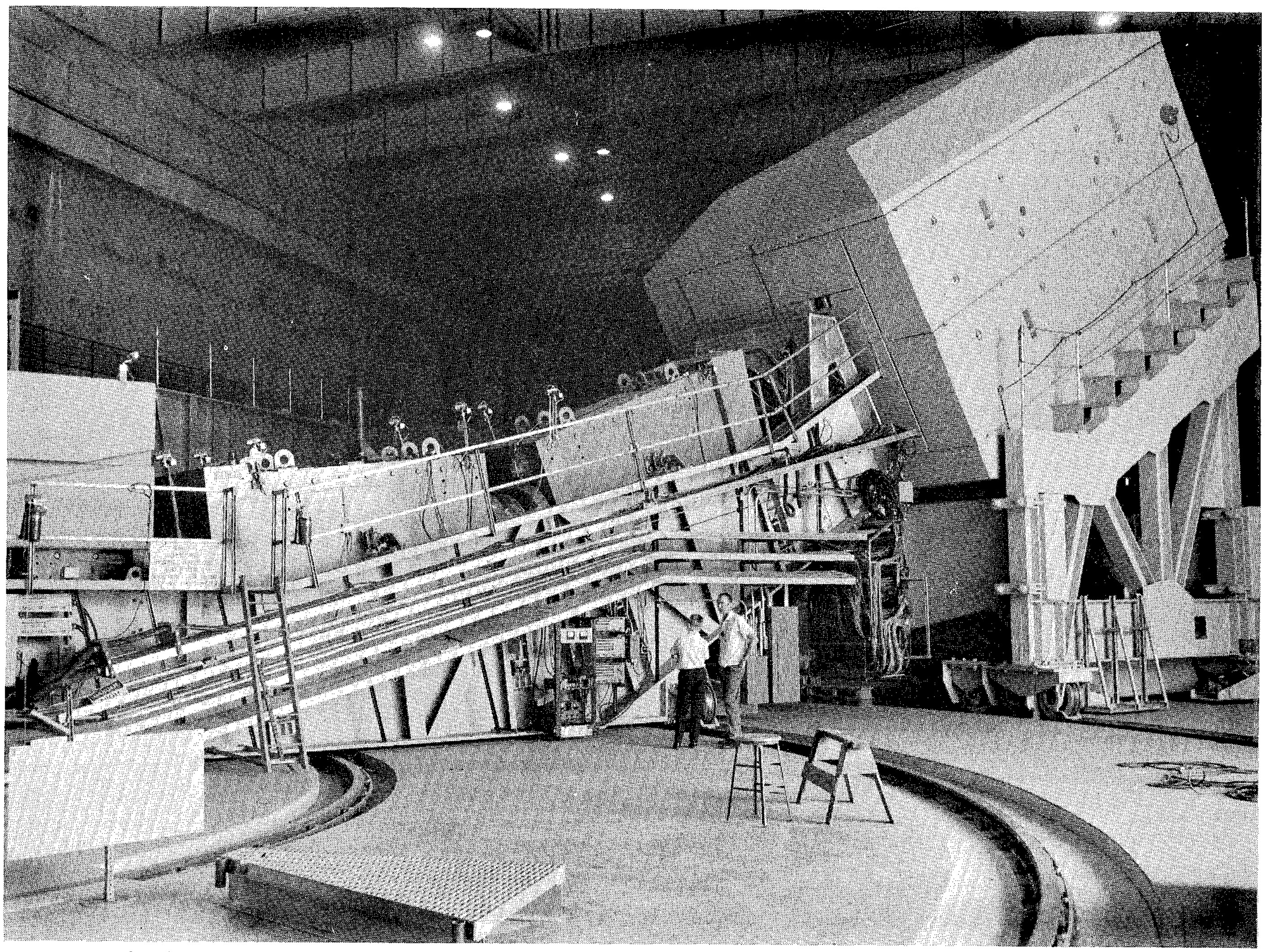
IN THIS ISSUE



This is a photograph of the 8 GeV/c spectrometer in End Station A at SLAC. This instrument is presently being used "in coincidence" with the larger 20 GeV/c spectrometer in an experiment, E-114, that measures the photoproduction of the new psi particles. Though the prospects were uncertain at the outset, this photoproduction technique has proved to be a very useful method for creating psi particles and for measuring some of their important properties. This issue of the *Beam Line* contains a full description of Experiment E-114 and also some supplementary information on the End Station A spectrometers.

PSI PHOTOPRODUCTION

Contents

8 p.m. to 8 a.m., Tues.-Wed. Jan. 28-29 (R. Fowkes). Psi's are now all over the place! Add T-178 to SP-16, 17 and E-114! E-114 now has ∿ 13 or 14 psi(3105) events and T-178 has at least one clean event . . .

--Accelerator Operations Log

Accelerator shift reports at SLAC are usually rather terse summaries of machine performance and of any problems that were encountered. The particular report shown above, however, says quite a bit more. A little more than two months after the original psi-particle discoveries at SPEAR and at Brookhaven National Laboratory (BNL), there were already several other experiments in progress to study these particles. In this article we'll describe these other experiments briefly, with our main emphasis on the promising results that are being obtained from SLAC Experiment E-114. As with the original experiments, the new work has two distinct approaches.

1. Two Kinds Of Experiments

Electron-positron storage rings such as SPEAR can produce psi particles in almost unlimited quantities and in a way that allows their decays to be studied both simply and with high precision. Since previous issues of the *Beam Line* (January 1975, and the special issue of December 5, 1974) have described the storage ring work on psi particles quite thoroughly, we shall simply note here that psi studies are continuing at SPEAR (two experiments) and at the Italian (ADONE) and German (DORIS) storage rings.

The psi particles can also be created or produced in the collisions between high-energy proton or electron beams with stationary targets of liquid hydrogen (protons) or heavier nuclei. The primary example of this second kind of experiment is the original BNL study, in which a beam of 28 GeV protons was directed against a beryllium target. In experiments of this kind, the encounter between beam particle and stationary target is brief but not very delicate, and almost anything can happen. It is possible to produce an occasional psi particle--perhaps in any of several different ways--and the created psi's are detected by observing their decay into either an electron pair (e^+e^-) or a muon pair ($\mu^+\mu^-$).

This second type, a *production* experiment, is quite "dirty." That is, fewer psi's are produced, with poorer mass resolution, and in a more confused way than is the case with storage rings. Since this is so, why should we bother with such experiments? The answer to this question can be given in the following way: Storage ring experiments can tell us most of what we want to know about the *decays* of the psi particles, but we would also like to know as much as possible about the ways in which the psi's *interact with other particles*. So let's turn now to a description of how such information can be obtained.

2. A Beam Of Psi Particles?

Ideally, we would like to be able to take a beam of psi particles and bounce it off the protons in a liquid hydrogen target, for example. Such psi-proton interactions would tell us a great deal about the psi--is it a strongly interacting particle, like the proton and the neutron,

PROPOSAL TO MEASURE Ψ PHOTOPRODUCTION OR ELECTROPRODUCTION AT SLAC USING THE 20 GEV and 8 GEV SPECTROMETERS IN COINCIDENCE FOR e AND μ PAIRS

Univ. of Wisconsin	SLAC
U. Camerini	R. L. Anderson
J. Learned	D. Sherden
R. Prepost	C. Sinclair
C. M. Spencer	D. Ritson
D. Wiser	W. W. Ash

or is it something else?

Although previous *Beam Line* articles have emphasized the comparatively long life of the psi (about 10^{-20} second), this lifetime is not long enough to permit the creation of a separate beam of psi particles. The best we can hope to do in approaching this goal is to create a psi particle *near* a proton and then let it interact with the same proton. Actually, this is a tried, and sometimes true, technique in high-energy-physics. The biggest problem that occurs in experiments of this kind is having a clear enough understanding of the *initial production* part of the process so that it can be cleanly separated from the *subsequent interaction*.

The most reasonable method of doing this seems to be the technique called *photoproduction*, in which a beam of high-energy photons (or gamma rays) is directed against a target and the resulting products are detected. The reason for preferring this photoproduction technique is that the storage ring experiments have given us, we believe, the required understanding of how the psi particles are initially produced. Since this is an important point, we can illustrate the comparison between psi production in storage-ring and photoproduction experiments by referring to the two parts of Fig. 1.

3. What Can Be Measured?

With the comparison given in Fig. 1 in mind, we now turn to a discussion of the characteristics of the psi particles that a photoproduction experiment should be able to measure.

Total cross section. In certain of its properties the psi(3105) is quite similar to the class of particles known as the *vector mesons*. Because of this similarity, theoretical physicists have been able to calculate the cross section (or probability) for creating psi particles by photoproduction. If it turns out that psi photoproduction is a very rare occurrence, this fact would be strong--and surprising--evidence that the psi's were not members of the *hadron* family of particles which respond to the strong nuclear forces in nature.

Angular distribution. Some of the created psi particles which interact with protons in the target will emerge almost along the direction of the incoming photon beam, while others will scatter at larger angles. The small-angle scatterings correspond to peripheral or "grazing" collisions with target protons, while the larger angle events represent more direct hits. A measure of this pattern of angular distribution yields important information about the character of the psi-proton interaction.

Energy dependence. In order to produce any psi particles at all, the incoming beam must contain photons which have more than a certain minimum amount of energy. What happens to the photoproduction process when the energy of the photon beam is increased above this "threshold" energy? Does the cross section also increase? Is the threshold actually where we think it is? These questions can be answered by measuring the energy dependence of the psi photoproduction process.

Inelastic interactions. So far we have assumed that the created psi particle simply scatters from a target proton, leaving both the psi and the proton intact after the collision.

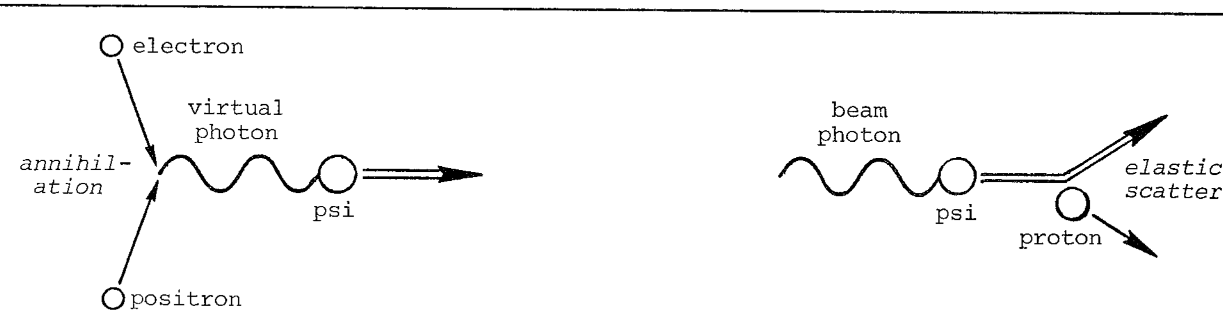


Fig. 1--A comparison of psi-particle production in electron-positron annihilation (left) and in photoproduction (right).

On the left, the collision of an electron and a positron is a storage ring such as SPEAR results in the annihilation of the two particles and the formation of a a transitory intermediate state of pure electromagnetic energy which is called a *virtual photon* or a *virtual gamma ray*. This intermediate state can then rematerialize into a psi particle, as shown, or into many other possible combinations of new particles. The newly created psi particle eventually decays into other particles, but this decay is not shown in the sketch.

On the right, a beam of high-energy photons or gamma rays is directed against a liquid hydrogen target. While in the vicinity of a hydrogen nucleus (which is a single proton), one of the incoming beam photons converts itself into a psi particle, which then undergoes a glancing collision with the nearby proton. When no new particles are created in the psi-proton collision, the process is called *elastic scattering*. After scattering, the psi particle eventually decays into other particles, but this decay process is not shown in the sketch.

But there will also be cases in which the psi-proton collision results in the creation of other new particles, and studying such "inelastic" collisions also provides information about the nature of the psi.

"A" dependence. The letter "A" is used to indicate the number of nucleons (either protons or neutrons) that constitute the nucleus of the different kinds of elements. For example, A = 1 (one proton) for the simplest element, hydrogen; and A = 9 (4 protons and 5 neutrons) for the common form of the element beryllium. By using targets made of different elements, the A dependence of the cross section for psi photoproduction can be measured, and such a measurement provides a check of the simple picture that is used to describe the process by which an incoming photon is converted to a psi particle before it interacts with a target nucleon.

Electroproduction. A beam of electrons can be used instead of a photon beam in particle-production experiments. We expect that the incoming electrons will first produce photons in the target, and that these photons will then interact to produce psi particles. It is possible, however, that electrons might create psi particles in some novel, direct way. It is also possible that the differences between the "real" photons in an actual photon beam and the "virtual" photons from electrons will have some significance in psi production.

Psi(3695)? Others? Although the psi(3695) is expected to be more difficult to photoproduce because of its larger mass and (probably) lower cross section, this particle would certainly be looked for in a psi-photoproduction experiment. In addition, it is conceivable that photoproduction would create other previously undiscovered particles that might not show up in storage ring experiments.

To summarize, the characteristics that were described briefly above are all well worth investigating, and we turn now to a discussion of the general features that a photoproduction experiment should have if it is to study these characteristics.

4. *How To Photoproduce*

A photon beam is directed against a thin target in the experimental area. Most of the photons in the beam will pass directly through the target without interacting at all. Of those which *do* interact, only a small fraction will result in the production of psi particles. The psi particles will then decay, and in the case of the psi(3105) the decays will occur in approximately the following pattern: 5% will decay into an electron-positron pair (e^+e^-); 5% will decay into a muon pair ($\mu^+\mu^-$); and the remaining 90% will decay into various combinations of strongly interacting particles (the large family of particles called *hadrons*).

Since the psi(3105) has a very well defined mass of 3105 MeV, the energy that is available when this particle decays is also a very well defined amount. When the decay psi(3105) $\rightarrow e^+e^-$ occurs, the electron and positron leave the scene of the decay with energies that must add up to the total energy that was available from the psi. Thus the basic requirement for a psi-photoproduction experiment is to set up *two* particle detectors behind the target--one to look at the electrons and the other at the positrons, and both able to measure the energy that the e^+ and the e^- are carrying. With this kind of an experimental set-up, production and subsequent decay of a psi particle will be indicated by the following "signature":

(1) An electron and a positron each arrive at their respective detectors *at the same time* ("in coincidence").

(2) The energies carried by the detected electron and positron add up to the energy of the psi particle.

Although these requirements sound relatively simple, in practice there will be some difficult problems. Perhaps the most difficult is the fact that the high-energy photon beam will produce in the target a veritable flood of other kinds of particles for each psi particle it creates. So any practical experimental set-up will need an elaborate filtering system that is able to pick out "a needle in a haystack"--there will be literally millions of unwanted particles for each wanted psi particle.

The features just described are generally applicable to the psi-production experiments that are presently being carried out at SLAC and at several other laboratories. In the next section we zero in on the specific psi photoproduction experiment that is being done at SLAC as a collaborative effort between physicists from SLAC and from the University of Wisconsin.

5. *Experiment E-114 At SLAC*

The photon beam for E-114 is obtained by directing the electron beam from the SLAC accelerator against a thin aluminum disk located near the end of the A leg of the Beam Switchyard. About 5% of the beam electrons produce high-energy photons, or gamma rays, by interacting with the material in the thin aluminum *radiator*. Just downstream of this radiator there is a magnet which deflects the leftover electrons out of the way into a beam dump, while the newly created photons pass through the magnet undeflected on their way toward the experimental target in End Station A. (The saga of the power supply for this critical beam-dump magnet was described in the last issue of the *Beam Line*.)

In End Station A the experimental target is located at the common pivot-point of the large magnetic spectrometers. A clever target-mounting scheme allows the experimenters to select any of several different target materials from a remote location: liquid hydrogen, liquid deuterium, beryllium, aluminum, or tantalum.

The nucleus of deuterium ("heavy hydrogen") consists of one proton and one neutron, and in this experiment the proton and the neutron act in pretty much the same way. Thus deuterium is used for most of the experimental running because it gives twice as many events as hydrogen would during the same period of time.

Figure 2 shows the 8 GeV and 20 GeV spectrometers in End Station A that are used as the "double-arm" detection system for Experiment E-114. Psi particles can be detected with this

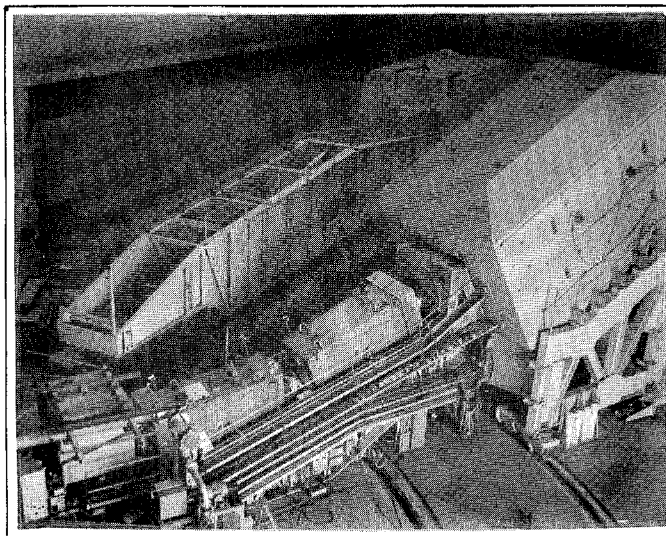


Fig. 2--This photograph of the 8 Gev (foreground) and 20 GeV spectrometers in End Statior A was taken about five years ago. These two large instuments are presently being used in a "double-arm" system in Experiment E-114 to detect the e^+e^- and $\mu^+\mu^-$ pairs into which the psi(3105) sometimes decays. Since pair detection must be simultaneous (within 10^{-9} second) the spectrometers are said to be "in coincidence." Although the properties of the two spectrometers are quite different, in this particular experiment they function largely as a symmetric pair.

system through observation of either an e^+e^- pair or a $\mu^+\mu^-$ pair. The spectrometer arms are set at angles of about 10° on either side of the straight-ahead direction of the incoming photon beam, and the magnetic-field strength in the spectrometers' bending magnets is adjusted so that only electrically charged particles of the desired momentum are able to "snake" their way through to the particle detectors located at the back end of each spectrometer.

The particle detectors are basically of two kinds: (1) *shower counters*, which are made either of leaded glass or of a "sandwich" of lead strips alternated with plastic scintillator segments; and (2) *muon telescopes*, which consist of alternate slabs of iron and plastic scintillator. High-energy electrons which strike matter create an electromagnetic cascade or shower which contains a large number of lower energy photons and e^+e^- pairs; these are detected in the shower counters. High-energy muons on the average penetrate much more deeply into matter before they interact; thus particles which pass all the way through the muon telescopes are identified as muons.

The most common kind of unwanted particle in the detection system is pi-mesons (pions), which are created many thousands of times more copiously in the target than are psi particles. The pions that make their way up through the spectrometers to the particle detectors are rejected in the following way: (1) neither the shower counters nor the muon telescopes are very efficient in counting pions. (2) In addition, there is a gas-filled *threshold Cerenkov counter* in the detection system that is adjusted to count electrons but not pions.

How it's working. The main limitation on an experiment such as E-114 is the *rate* at which "good" events can be measured. Sometimes it happens that the filtering system that is used to reject unwanted particles must be so elaborate that it also rejects most of the *wanted* particles --in which case the experiment rapidly become uninteresting. As it turned out, E-114 didn't take very long to become quite interesting. In fact, we had detected our first psi particle within the first hour of our run; and as of this writing (Feb. 28) the most favorable experimental conditions produce about 50 events per day of the decay process psi(3105) $\rightarrow e^+e^-$ and about an equal number of psi(3105) $\rightarrow \mu^+\mu^-$.

As a check to assure ourselves that these events are the real McCoy, we can work backward from the detected electron and muon pairs and calculate the mass of the decaying particle that is producing them. A calculation of this kind is shown plotted in Fig. 3, which is persuasive evidence that we are indeed seeing the decay of the psi(3105). (Fig. 3 on next page.)

6. *Other Photoproducers*

There are, or were, several other photoproduction experiments going on that we would like to mention briefly. As of the end of February, 1975, their status could be summarized as follows:

At SLAC, a short test run (T-178) in an experimental set-up behind End Station B (Beam Line 19) had detected about 5 events around the psi(3105) mass. This work was done by the group of physicists from SLAC, M.I.T. and the University of Massachusetts who have been collaborating in a study of the electroproduction of hadrons in Experiment E-97.

At Cornell, a few events at the mass of the

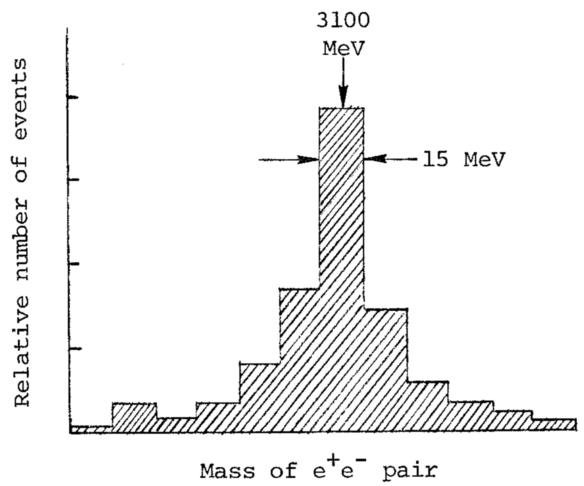


Fig. 3--The mass distribution of about 100 e^+e^- events that were detected in a few days of running on E-114. These data clearly demonstrate that the events are coming from the decay process psi(3105) $\rightarrow e^+e^-$.

psi(3105) were observed in two recent photoproduction experiments. These experiments were able to establish a limit for the total cross section, and one of them is now being rerun with certain improvements. The Cornell electron synchrotron has a maximum beam energy of about 12 GeV, which means that their studies are somewhat restricted because they cannot go much above the energy threshold for psi production.

At Fermilab, a photon beam of very high energy (soon to reach 300 GeV!) but of limited intensity is being used in an experiment that looks at psi decay into muon pairs. Data on about 70 events from this experiment has already been published, and the work is continuing.

Some early indications. Although a good deal more work will have to be done before these photoproduction experiments--including our own E-114--can be interpreted in a definite way, the early indications seem to point toward a somewhat smaller cross section than would be expected if the psi(3105) were simply a conventional hadron. In addition, the pattern of angular distribution of the decay products so far observed appears to be different from that seen for the vector-meson family of particles. At this early stage, however, the most important fact is simply that photoproduction has been established as an effective technique for studying some of the significant properties of these remarkable new particles. It is already clear that these photoproduction experiments will be a powerful tool that can be used to complement the storage-ring studies in answering some of the unexpected questions that the discoveries of the psi particles have raised.

--Bill Ash

ON THE NEW NARROW RESONANCES

M. B. Einhorn & C. Quigg
Fermilab

Abstract

After considering several alternatives, we conclude that the most likely explanation for the new particles is that they are bound states of a new quark-antiquark pair.

* * * * * *

We have completed an exhaustive and searching study of the possible interpretations of the new bosons discovered recently at SPEAR and at BNL.[1] It is our nearly inescapable conclusion that the new particles are quark-antiquark bound states of a new, fourth quark. We call the new quantum number carried by the fourth quark *Panda*,[2] and we suggest the name Pandamonium for the new particles. The quark configuration of the lowest-mass vector state is depicted in Fig. 1.

Figure 1: (Ortho-) Pandamonium ground state, which we identify with the J/ψ(3105).

Note added: While this paper was in preparation, we learned that similar results have been obtained by several other workers. The length limitation on Letters submitted to this journal discourages us from giving a complete set of references.

References

1. J. J. Aubert *et al.*, *Phys. Rev. Lett.* 33, 1404 (1974). J.-E. Augustin *et al.*, *ibid.*, 1406, and private communication.

2. We chose this name because of the panda's well-known shyness, and tendency to stay among his own kind. The great mass of the giant panda has also influenced our thinking.

Submitted to *Physical Review Letters*

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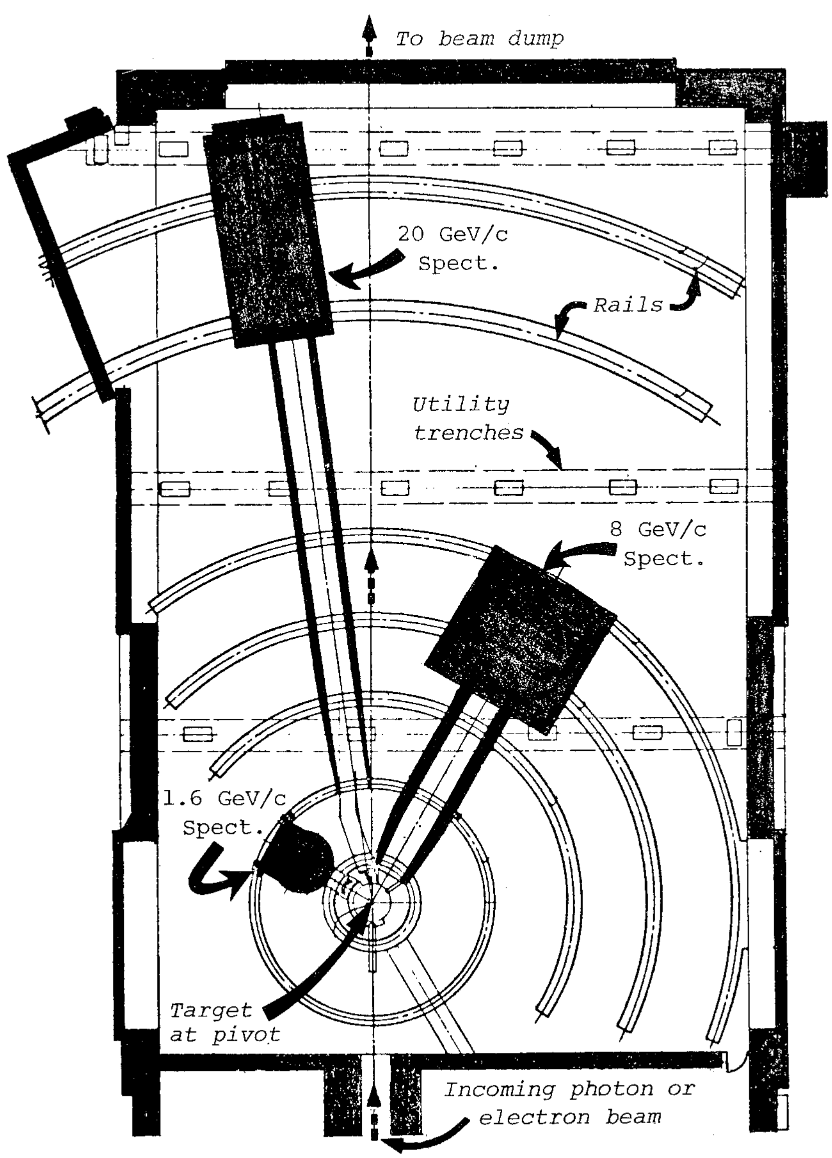
END STATION A SPECTROMETERS

This brief review (mostly figures and captions) was put together after we had received Bill Ash's story on "Psi Photoproduction" that appears in this issue. Our intent is to provide some additional spectrometer information that may serve as a useful supplement to his article. The electron-scattering and photoproduction experiments for which the End Station A spectrometers were built have traditionally been the "bread and butter" work at electron accelerators, and psi photoproduction is yet another example of how well these massive but precise instruments have earned their keep at SLAC.

We'll proceed as follows:

1. End Station A layout
2. The spectrometer facility
3. Scattering and photoproduction
4. The 8 and 20 GeV in more detail
5. Particle detection
6. Some odds and ends

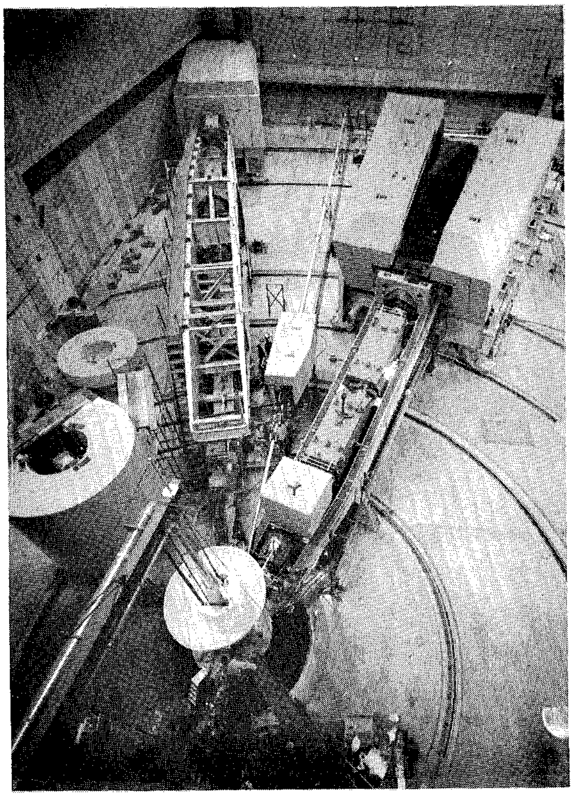
1. END STATION A LAYOUT



A plan view of End Station A showing the 1.6, 8 and 20 GeV/c magnetic spectrometers. These instruments are named for the maximum particle *momentum** that each can successfully measure. All of the spectrometers are mounted on wheeled carriages which ride on the circular rails shown in the figure. The fixed end of each spectrometer is connected to a common pivot point at which the experimental targets are located. (The pivot is a sawed-off section of a 16-inch battleship gun.) The path of the incoming electron or photon beams (dashed arrows) comes in from the Beam Switchyard, through the target, and then out through the east wall of the End Station to a power-absorbing beam dump--contained in a vacuum envelope all the way. General radiation shielding is provided by the thick walls and roof of the End Station. Particular experiments may also require additional shielding at local "hotspots." Much of the perimeter wall of End Station A is built up of stacked concrete shielding blocks, rather than structural concrete, so that unusual experimental set-ups can be accomodated with a crane instead of dynamite.

*Although *momentum* (GeV/c) and *energy* (GeV) are not the same thing, the difference is not very important at energies of many GeV. The spectrometers are therefore called, *e.g.*, "the 20 GeV," although "20 GeV over c" is correct.

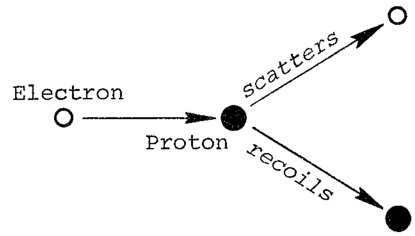
2. THE SPECTROMETER FACILITY



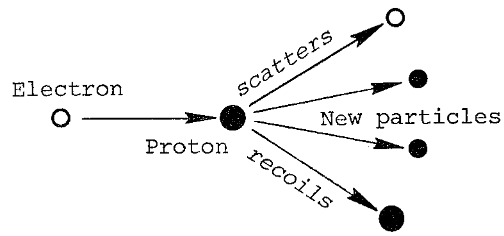
This photograph shows the three spectrometers in End Station A in about the same orientation as the previous figure. On the right, the massive concrete blockhouse at the end of the 8 GeV spectrometer has been split apart to give access to the particle-detection equipment located inside. This view makes it evident why the 20 GeV spectrometer is limited to angular positions from about 0° to 20° with respect to the beam direction (the thin vacuum pipe leading to the back wall of the end station). The 8 GeV spectrometer can cover the angular range from about 12° to 100°, while the 1.6 GeV can cover from about 25° to 165° (nearly directly backwards). In this photograph the 8 and 20 GeV spectrometers are both positioned at relatively small angles; this arrangement is quite similar to the set-up that is presently being used to study psi photproduction in Experiment E-114.

The scattering and photoproduction experiments described in the right-hand column of this page require precise measurements of both the *angle* and the *momentum* of particles coming from the target. The three spectrometers can each measure angles with an accuracy of about .02 degree. Momentum can be measured with an accuracy of about 0.15% of the momentum setting that is being used. This is achieved by a combination of magnetic analysis and the use of counter arrays called *hodoscopes*.

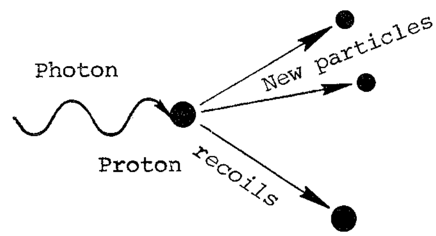
3. SCATTERING AND PHOTOPRODUCTION



(a) ELASTIC ELECTRON SCATTERING



(b) INELASTIC ELECTRON SCATTERING



(c) PHOTOPRODUCTION

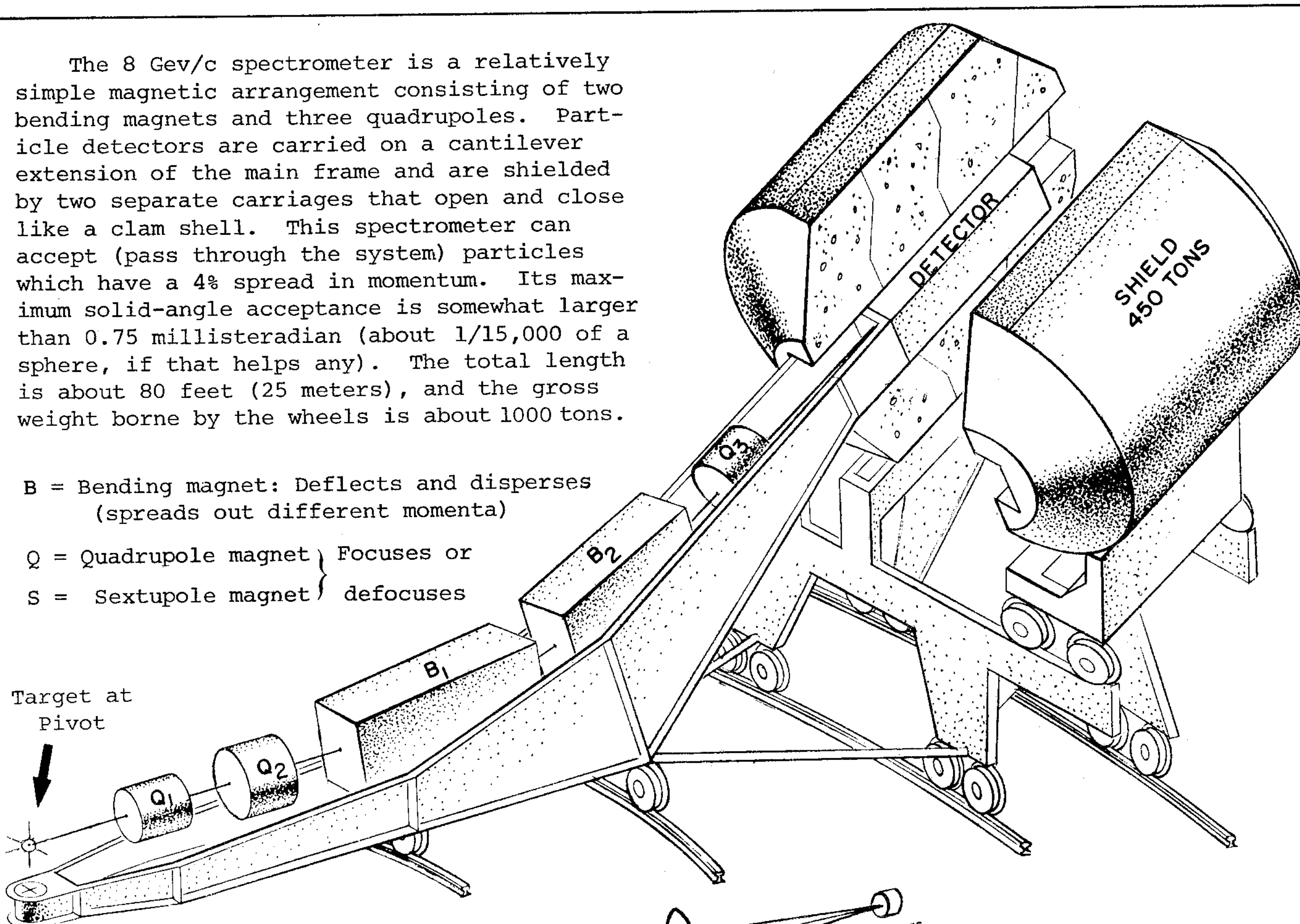
These sketches illustrate the basic processes involved in *elastic* and *inelastic electron scattering* and in *photoproduction*. [The process shown in (b) can also be called *electroproduction*.] These are the most common kinds of experiments for which the End Station A spectrometers are used. Depending upon the experimental conditions, a spectrometer can be used to detect the scattered electron, or the recoil proton, or one of the newly created particles (it must be electrically charged). The use of only one spectrometer is called a "single-arm" experiment. The psi photoproduction experiment now in progress, E-114, makes use of the 8 and 20 GeV spectrometers in a "double-arm" arrangement for simultaneous detection of either the e^+e^- or $\mu^+\mu^-$ (muon) pairs that sometimes emerge after the production and subsequent decay of the psi(3105) and psi(3695) particles. The use of two spectrometers for simultaneous detection is called a "coincidence" experiment. The photon beam in (c) is obtained by first running the SLAC electron beam into a thin target or *radiator* near the end of the Beam Switchyard.

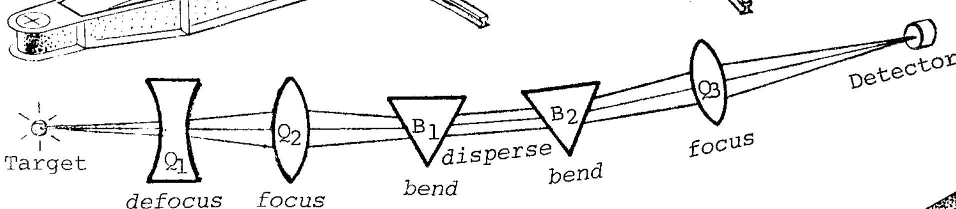
4. THE 8 AND 20 GeV IN MORE DETAIL

The 8 Gev/c spectrometer is a relatively simple magnetic arrangement consisting of two bending magnets and three quadrupoles. Particle detectors are carried on a cantilever extension of the main frame and are shielded by two separate carriages that open and close like a clam shell. This spectrometer can accept (pass through the system) particles which have a 4% spread in momentum. Its maximum solid-angle acceptance is somewhat larger than 0.75 millisteradian (about 1/15,000 of a sphere, if that helps any). The total length is about 80 feet (25 meters), and the gross weight borne by the wheels is about 1000 tons.

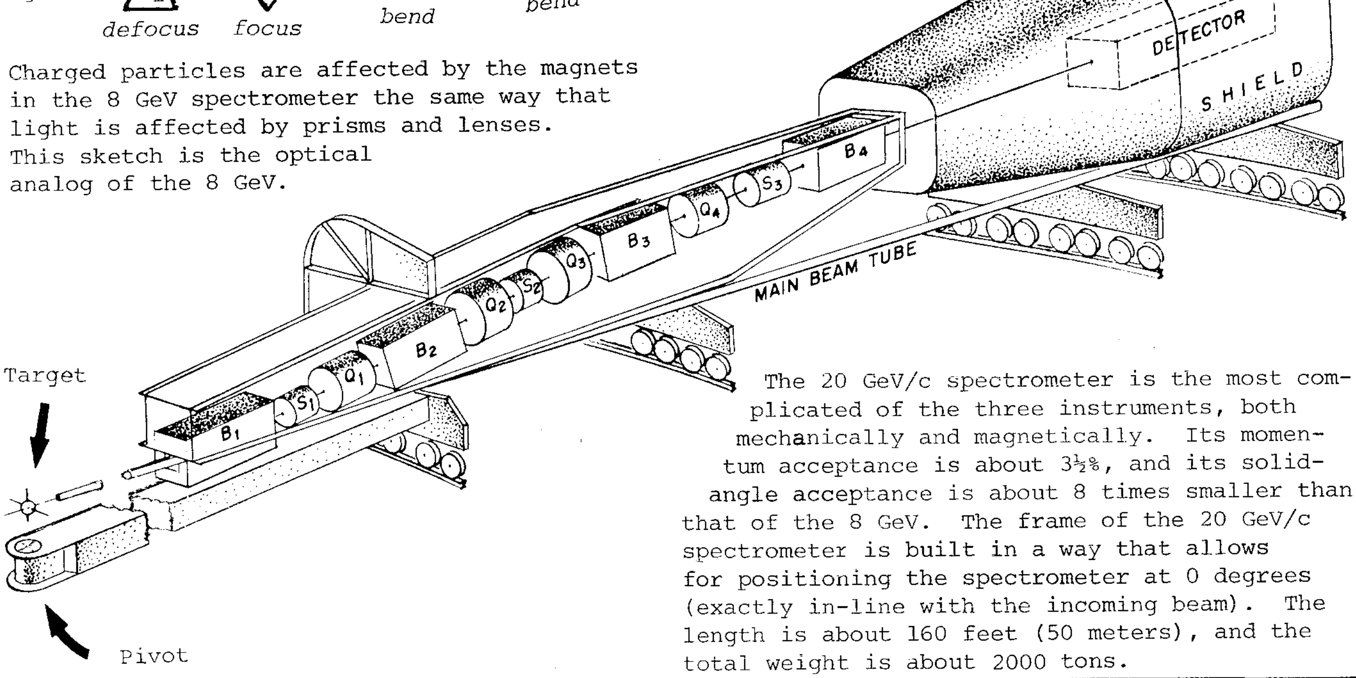
B = Bending magnet: Deflects and disperses (spreads out different momenta)

Q = Quadrupole magnet } Focuses or
S = Sextupole magnet } defocuses





Charged particles are affected by the magnets in the 8 GeV spectrometer the same way that light is affected by prisms and lenses. This sketch is the optical analog of the 8 GeV.

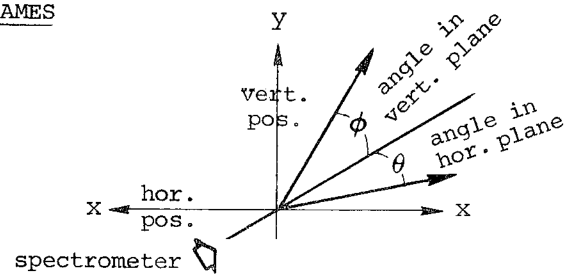


The 20 GeV/c spectrometer is the most complicated of the three instruments, both mechanically and magnetically. Its momentum acceptance is about 3½%, and its solid-angle acceptance is about 8 times smaller than that of the 8 GeV. The frame of the 20 GeV/c spectrometer is built in a way that allows for positioning the spectrometer at 0 degrees (exactly in-line with the incoming beam). The length is about 160 feet (50 meters), and the total weight is about 2000 tons.

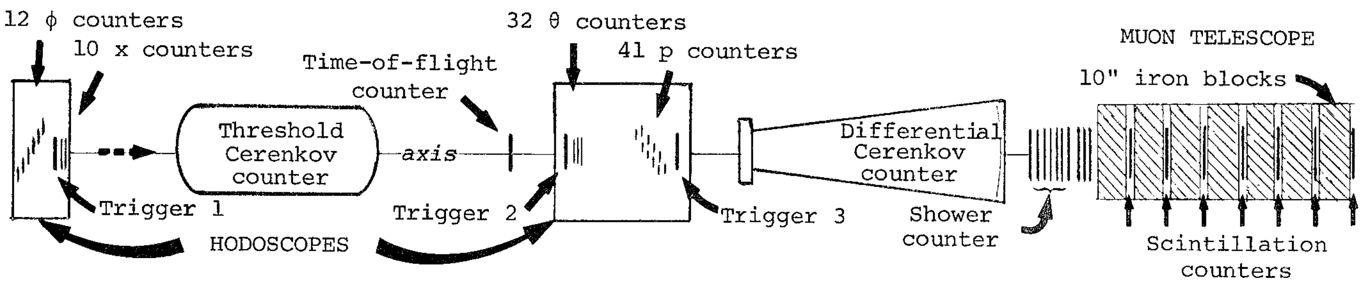
5. PARTICLE DETECTION

KEY TO COUNTER NAMES

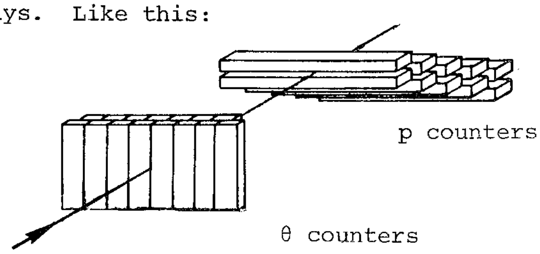
Name	*What It Measures*
p	momentum of particle
x	horizontal displacement from axis
y	vertical displacement from axis
phi ϕ	angle from axis in vertical plane
theta θ	angle from axis in horizontal plane



TYPICAL ARRANGEMENT OF COUNTERS IN THE 20 GeV SPECTROMETER



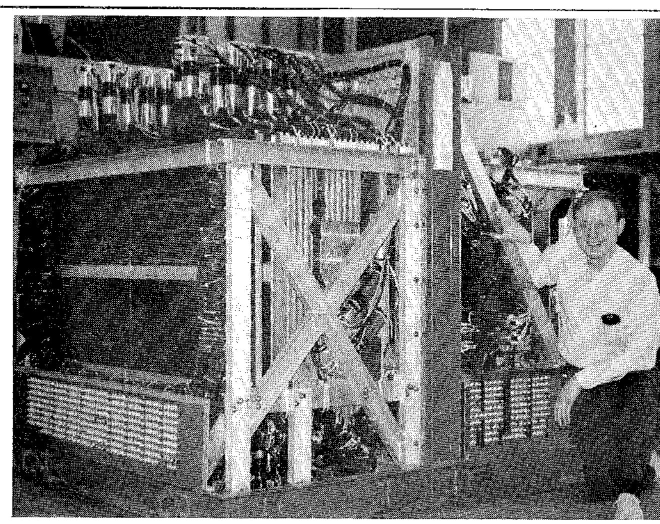
Since the SLAC spectrometers have the unusual property of focusing point-to-line (all incoming particles that start at the same point will eventually be focused in a vertical or horizontal narrow band--even though their momenta may differ), the hodoscopes consist of long thin counters that are stacked in parallel arrays. Like this:



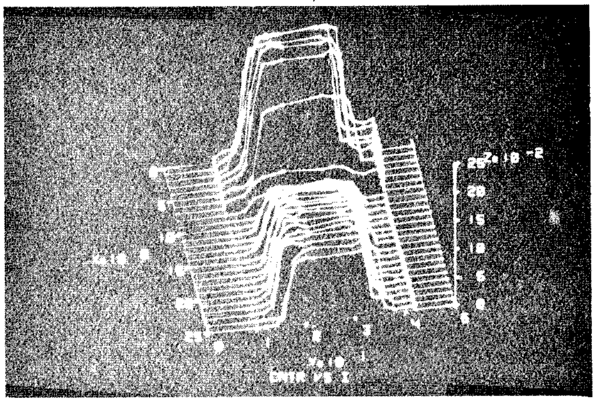
The hodoscopes take care of measuring the momenta and angles of the incoming particles. The additional job of identifying the particles can be handled in several different ways. Two particles of equal momentum but different mass will travel at different *velocities*. Either the time-of-flight system or the Cerenkov counters can distinguish between particles on the basis of their velocity. Also, electrons (or positrons) can be recognized by the fact that they produce a cascade of photons and e^+e^- pairs in a *shower counter*. Muons are identified by the fact that they penetrate much more deeply than electrons or pions before interacting, and are thus able to make it all the way through the *muon telescope*.

ELECTRON-PION DISCRIMINATION: THE "BLUE BOX"

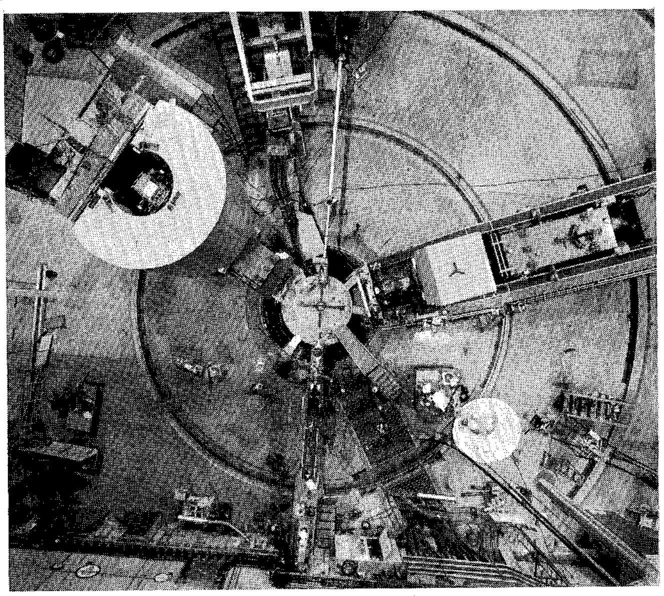
Former MIT graduate student Paul Kirk is shown here with the "Blue Box," an elaborate counter array that was used in the 8 GeV spectrometer to distinguish electrons from pions. Although this device is not properly a hodoscope, the parallel stacked array of long scintillation counters makes it somewhat resemble a hodoscope. Although the "caves" inside the concrete shielding huts on the spectrometers may appear from the illustrations to be small, a large amount of non-miniaturized stuff can be crammed into them. In the case of the 20 GeV spectrometer, for example, the free space inside the concrete shield is about 33 feet long--enough to take the large collection of counters shown above.



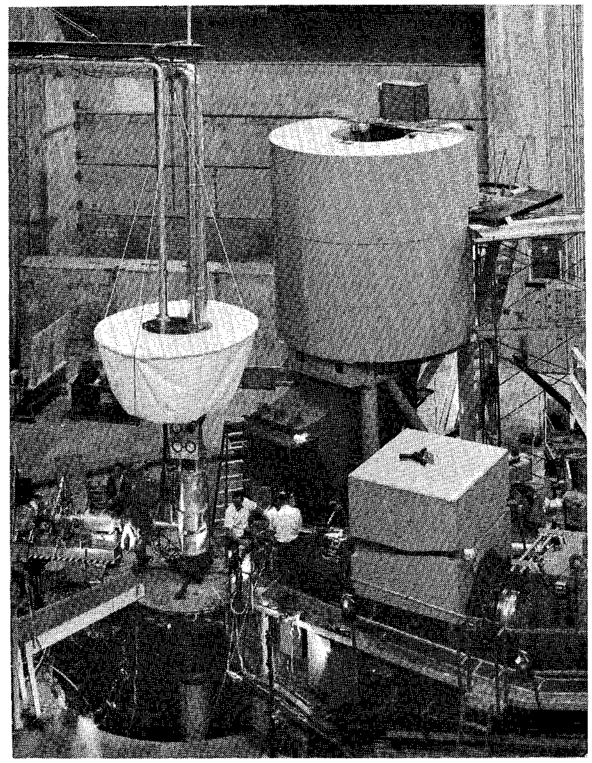
6. SOME ODDS AND ENDS



This is an example of the two-dimensional isometric data displays that the subroutine OPUS 2 can generate on the XDS 9300 computer in the End Station A counting house. We'd like to be able to explain that the picture we're seeing is the sharp rise in cross section that occurs with the production of the new psi(7700) resonance. The fact is, however, that we don't have the foggiest about what this particular picture is.



This is a straight-down view of the pivot point about which the three End Station A spectrometers can rotate. The beam from the accelerator comes in from the bottom of the photo. Beam particles (or photons) that do not interact in the pivot-point target are held in vacuum (small pipe) until they reach the beam dump beyond the end station. This view shows clearly the "kinked" arrangement through which the 20 GeV spectrometer (top) is enabled to take up a position at 0 degrees (straddling the exit pipe). This perspective also makes it easy to see the range of angular coverage that the 1.6 GeV (about 140°) and 8 GeV (about 90°) spectrometers can handle.



This photo of the pivot point in ESA gives some sense of scale to the apparatus. Ed Taylor of SFG is on the right, but we can't make out the others (three others). Rising up in the middle of the pit under the target region is the barrel of the 16-inch battleship gun which carries the mechanical load. In this view the 1.6 GeV spectrometer appears to be trying to impersonate a 575-ton can of coffee. It's photographs like this one, where every second object in view checks in at three digits worth of tons, that tend to reinforce our faith in the eventual return of the steam locomotive.

To conclude, finally, it's probably worth remembering that SLAC's End Station A spectrometers have done some pretty useful work even before the present psi-photoproduction experiment. Here's the view of a noted physicist, Julian Schwinger, writing in the January 1975 issue of the *Proceedings of the National Academy of Science of the USA* (paper submitted in October 1974):

> No experiment in the recent history of high energy physics research has had more impact on the theoretical community at large than the deep inelastic scattering experiment of the MIT-SLAC collaboration. . . .

--Bill Kirk

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Stanford Linear Accelerator Center
Stanford University
P.O.Box 4349
Stanford, California 94305

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Contributors

Herb Weidner, Bin 20, x2521
Dorothy Ellison, Bin 20, x2723
Harry Hogg, Bin 33, x2441

Photography & Graphic Arts

Joe Faust, Bin 26, x2429
Walter Zawojski, Bin 70, x2778

Production

George Owens, Bin 82, x2411

Editor

Bill Kirk, Bin 80, x2605

THE REACH OF LIGHT

For a long period astronomers unsuccessfully endeavored to determine the distance between the stars and the earth, and it is only within a comparatively short time that the interesting problem can be said to be solved. The distance which separates us from the nearest stars is, according to M. Arigo, about 206,000 times the distance of the earth from the sun--more than 206,000 times 95,000,000 of miles. Alpha, in the constellation of the Centaur, is the star nearest the earth; its light takes more than three years to reach us, so that, were the star annihilated, we would still see it for three years after its destruction.

--*Scientific American*, May 1857

One of the most remarkable astronomical announcements has recently been quietly made from the Mount Wilson Observatory, namely the first reliable determination of the distance of a spiral nebula from the earth. We have known for a decade that these extraordinary objects must be very remote; now Major E. P. Hubble has shown that they are even farther away than had been thought. Hubble discovered last year some faint, variable, star-like points on the edge of the Great Nebula in Andromeda. Further study was laborious, but it became plain that these objects are really stellar, that their variability is regular and that it is of the so-called Cepheid type. What makes this class of variable stars so useful is that, in every case tested, the real or absolute brightness of such a star depends only on its period of variation. The longer the period, the brighter the star. Hence if an astronomer can detect a Cepheid, can find out how long it takes to vary and can determine how bright it looks, he can figure out at once how far off it is. Hubble's newly discovered variables in the Andromeda nebula are perfectly good Cepheids. He has worked out the periods for 10 of them. When their distances are computed, they are found to be substantially the same for all 10 and at the enormous distance of a million light years. The measurement leads to conclusions that are enough to make an astronomer gasp. The diameter of the nebula must be some 35,000 light years, and overall it must shine a billion times as brightly as the sun. Whether the nebula is actually composed of stars or whether something else may cause its light we do not yet know.

--*Scientific American*, March 1925

Beam Line Dist.	0-2	6-14	11-19	21-6	26-22	34-4	52-7	60-20	65-35	70-5	75-17	82-12	87-8	92-3
	1-15	7-2	12-8	22-13	27-3	40-65	53-42	61-21	66-16	71-56	78-24	83-9	88-27	94-12
	2-8	8-4	14-4	23-12	30-41	45-7	54-30	62-47	67-12	72-3	79-85	84-20	89-20	95-37
	3-6	9-3	15-5	24-11	31-7	50-25	55-31	63-19	68-10	73-13	80-8	85-23	90-3	96-15
	4-5	10-9	20-20	25-3	33-17	51-30	56-10	64-15	69-22	74-8	81-50	86-11	91-6	97-88