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AN EVALUATION OF THE 12-METER STREAMER CHAMBER

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The summer study of 1968 contains a proposal for the construction of a 12-meter streamer-chamber data-collection and analysis system (C4-68-57, Proposal for a 12-Meter Streamer Chamber by A. Odian, F. Villa, and I. Derado), estimated to cost about $5.5 million (less refrigerator and iron for the superconducting magnet.)

The major cost is for the 20-kgauss, 12-meter superconducting magnet, and the estimate was scaled from the cost of the BNL 25-ft bubble chamber magnet. The cost estimates cannot be taken too seriously.

Only one experiment has so far been done with the SLAC streamer chamber, and that one (rho production with a hydrogen gas target), could probably have been done as well or better by more conventional means. The chamber is now being moved and a second experiment will not start before late spring of '69.

TECHNICAL EVALUATION

Technically, the performance of the streamer chamber currently ranges from fair to excellent, in several areas of importance. These may be rated as follows:

1. The high-voltage problems are essentially solved, insofar as production and application to the chamber of the 600-kv pulses needed is concerned. The Marx generators, Blumlein transmission lines, pulse length and amplitude controls all seem to be excellent.

2. The method of producing the high voltage field in the chamber is not satisfactory. At present it is produced by arrays of wires outside the active volume of the chamber. This puts the top and bottom surfaces of the chamber volume into the strong electric field, allowing them to pick up and store charge on insulating surfaces. No attempt to provide conductivity to bleed these charges off seems to have been made. The result has been very serious "flares", which are corona discharges to various points on the chamber surface. Since these are much brighter than the streamers, they obscure the tracks, sometimes over large areas. In the short sequence I saw, almost every frame was disfigured by such flares. This is unfortunate, since problems of this sort also arose with other modes of spark chamber operation, and were successfully solved by not exposing the insulating surfaces to the high field region. This is most easily accomplished by putting the electrodes inside the chamber. Photography through a conducting surface is possible either by providing a transparent conducting layer on the surface to be photographed through, or by adding metal screens or wire planes of high transparency.

3. The quality of the present photographs is somewhat variable, even aside from the flares. As with the conventional wide-gap chamber, the intensity of the track depends on the angle it makes with the field. In the case

of the streamer chambers, strongly dipping tracks tend to become very bright (they may go to the track mode), obscuring and perhaps robbing the streamer tracks. The photographic quality of the SLAC pictures looks to me rather questionable for automatic data processing by machines like POLLY. This is not an intrinsic difficulty; I believe tracks of sufficiently high quality for POLLY processing are perfectly feasible with a streamer chamber; it is only that the first SLAC run has not produced them.

4. No attention has yet been paid to the clearing or memory-time problem. With wide-gap chambers this is always severe, and usually limits such chambers to a tolerable beam intensity a factor of ten or more less than narrow-gap sampling chambers. The memory time of the current chamber, with no clearing, is in the usual 20-30 μsec range. It is probably possible because of diffusion to distinguish tracks of different ages from each other; but a clutter of old tracks due to long clearing times is a disadvantage.

With wide-gap chambers, clearing by electric fields is of very limited value; tje canonical clearing rate in neon-helium mixtures is about 1.4 cm per microsecond, so that a 30-cm chamber with the track at the far side would take 20 μsec to clear. Extra planes of clearing wires can be introduced, as they sometimes are in cloud chambers, but this is not the best way either.

The best method is chemical clearing, using a deliberately introduced electronegative component like SO_2. This gives sensitive times, in proper concentration, of 2-4 μsec, without decreasing unduly the efficiency or track density of the in-time tracks.

5. The optical system proposed is borderline in quality and cost. The picture quality, with demagnification of 70, and a required depth of field over a meter, is marginal. Also, it is very expensive to run five 70-mm cameras, each yielding six inches of film per frame. The film cost is at least .25 per frame, including development, in large quantities. Thus a 1-million frame experiment would cost $250K for film alone. Given also the capability of the system to take many frames per pulse, it is quite possible for the film cost to approach $100K per day, which would put very sharp restrictions on the use of the system.

6. The depth-of-field problem in large streamer chambers is acute because of the wide aperture (e.g. f/2) lenses required; and it is not so much solved as ignored. A circle of confusion as large, or larger than the streamer image is permitted. The depth-of-field problem forces the use of large demagnification, with attendant limitations on accuracy. As the radius of the circle of confusion increases, a limit is reached when the effective speed of the lens decreases because the out-of-focus image covers too large an area in the film plane. At this point, one has to add more cameras focused at different depths. The use of image intensifiers as light amplifiers solves the depth-of-field problem by

permitting smaller lens apertures, but it introduces still worse problems of resolution, stability and complication.

7. The track accuracy of the streamer chamber has been the subject of considerable discussion. Without going into excessive detail, let us summarize by saying that the overall systems performance of the SLAC 2-meter chamber in its first experiment corresponded a value of 560 microns for the "setting error" parameter that is used as input to the track-fitting program; that number therefore includes all system errors including optics and magnetic field calibration. For a first experiment this is not bad. For straight tracks in the chamber (field off) the corresponding error, is $\sim$ 350 microns; this is to be directly compared to the values of about 1/3 mm usually quoted for the setting error of a narrow-gap optical or wire-chamber.

SYSTEM PERFORMANCE

Accuracy. The criteria developed during the course of the summer study concerning the precision of track measurement were

1. Momentum accuracy of 0.1 GeV/c or better, up to 100 GeV/c.

2. Transverse momentum accuracy of 20 MeV/c.

These criteria are intended to allow the analysis of not merely 4c fits but also of 1c fits, in which the mass of the missing neutral particle can be disttinguished between a neutral pion or higher masses.

The system as proposed fails to meet both these criteria. They can be met by increasing the magnetic field or improving the setting accuracy. It appears to be premature, for the reasons to be detailed later, to embark on a detailed study of this point now.

Detection of Neutral Particles. An additional criterion is the ability to detect forward-going neutral particles with high efficiency, and to determine with good accuracy their direction. Thus the system must be adaptable to the use of such detectors. The thin-walled streamer chamber offers no impediment to their external use. A more rigorous criterion, the desirability of detecting neutrals in any direction from the vertex, appears to be impossible of fulfillment in any detection device with visual readout; the streamer chamber comes as close as any to meeting it.

The detection of forward neutrals may be accomplished by the insertion of heavy radiators into the chamber (ignoring for the moment any resulting problems with the electric field), or by auxiliary external devices. The equivalent of one or several lead plates in the chamber suffers from the defect that it is difficult to provide both good angular discrimination and high efficiency of detection in a limited volume. The gamma or neutron conversion vertex can be located fairly well, but an independent measurement of gamma-ray direction, highly desirable in events with more than vertex (or pictures with more than one interaction) requires more space than ought to be allotted in an expensive magnetic field volume when the magnetic field is not being used.

FUTURE DEVELOPMENT

To summarize, then, there appears to be no disqualifying technical flaw in the concept of a large streamer chamber as a major component of a detection system for high energy use. Improvements in performance are certainly to be anticipated as more experience is gained in use. The major drawbacks to the existing proposal are connected with the great size of the system, which complicates the technology and increases the cost. Scaling the size of the magnet down by a factor of two would obviously produce considerable amelioration in the optical problems, as well as in other technical difficulties. This will be feasible only if the performance can be maintained or restored to a satisfactory level, by increasing the measurement accuracy and/or magnetic field.

It is apparent that further consideration of the use of large magnetic field streamer-chambers ought to be in the context of a competing system with one or more component spectrometers and neutral-particle detectors. Thus, it becomes undistinguishable from the generalized concept of a "hybrid" or multi-component detector system as developed from the original proposal of Fields et al. (See TM-). Thus, further work on the systems problems of the multi-component system takes precedence over detailed studies of improvements in the streamer chamber component; it may be more satisfactory to combine existing devices to obtain high performance than to try to obtain it from a single large streamer chamber.