NUCLEAR INSTRUMENTS AND METHODS 20 (1963) 208-212, NORTH-HOLLAND PUBLISHING CO.

THE APPLICATION OF THIN-PLATE SPARK CHAMBERS TO HIGH-ENERGY π-p EXPERIMENTS

E. BLEULER[*], D O CALDWELL[†], B ELSNER, D HARTING, L W JONES[††],
W. C. MIDDELKOOP and B ZACHAROV,
CERN, Geneva
and
M L PERL and C C TING
The University of Michigan, Ann Arbor, Michigan
Presented by L. W Jones

The spark chamber, as first described by Fukui and Miyamoto and developed as a useful tool for accelerator research by Cork and Cronin, has by now been used in many successful experiments. A particularly simple and successful method of constructing spark chambers with very thin plates was developed by Terwilliger and Meyer at Michigan It is against the background of these developments that we began to use the technique The particular innovations introduced by us are quite obvious and straightforward, but a description of the following experiments may indicate tricks useful to other experimenters

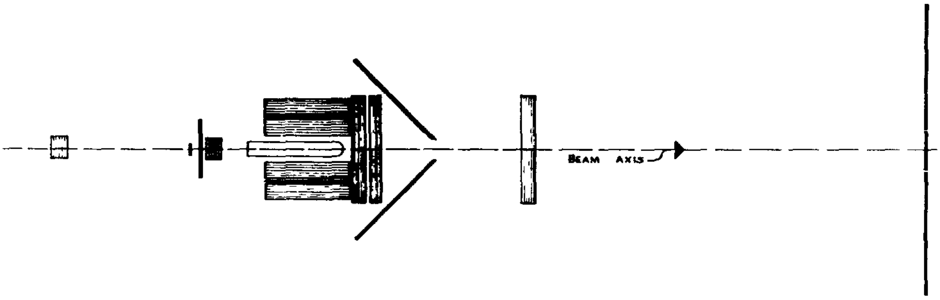

Fig 1 Plan view of spark chambers and trigger counters for elastic scattering experiment The first and last pairs of chambers are spaced by 24 inches

One feature of our experiments has been the use of thin-plate spark chambers spaced by some distance to sample two portions of a track in order to determine the angle of a track to a high precision A second feature is the folding of the images of the several spark chambers and their stereoscopic views using a number of mirrors in order to present all the chamber data on a single 35 mm film frame

In an experiment to study elastic pion-proton scattering at the Bevatron of the Lawrence Radiation Laboratory at energies of 2 to 5 GeV, an array of nine spark chambers was assembled around an 18 inch-long liquid hydrogen target This experi-

---

[*] J S Guggenheim Fellow, on leave of absence from Purdue University, Lafayette, Indiana

[†] National Science Foundation Senior Post-Doctoral Fellow, on leave from Massachusetts Institute of Technology, Cambridge, Massachusetts

[††] Ford Foundation Fellow on leave of absence from the University of Michigan, Ann Arbor, Michigan

ment was designed and executed by Jones *et al* [1]. The chambers were each of 6 gaps, using for plates 0.001 inch hardened aluminium foil (7 mg/cm^2). These were cemented onto lucite frames and the array cemented together with epoxy resin at reduced temperature, so that when warmed to room temperature the differential temperature coefficient of expansion drew the aluminium foils taut. The arrangement of spark chambers and scintillation counters is shown in plan view in fig. 1. The two front chambers spaced by 24 inches defined the direction of incoming beam pions to an accuracy determined by the position resolution of sparks in each chamber. For a resolution in each chamber of 0.5 mm, this corresponds to an angle resolution of 0.7 mm/60 cm, or about 1.2 milliradians. By similarly defining the angle of an emerging, diffraction-scattered pion using chambers spaced by the same distance, the scattering angle is determined to less than 2 milliradians. Particles scattered by angles greater than about 15° would not pass through 12 gaps of the chambers close to the target permitting angle measurements of about $\frac{1}{3}°$. This angular resolution was very important in this experiment in distinguishing the large-angle elastic events (corresponding to cross sections of several microbarns per steradian) from the background of two-prong inelastic events. The images of the central 7 spark chambers and their 90° stereo views were directed through a 36 inch diameter plastic field lens, the first and last chamber images did not use the field lens. An array of 13 plane mirrors directed and assembled the images of the chambers downward onto a 54 × 54 inch^2 mirror inclined at 45°, which in turn directed the images to the recording cameras. The camera used a 12 inch focal-length lens and was located 32 feet

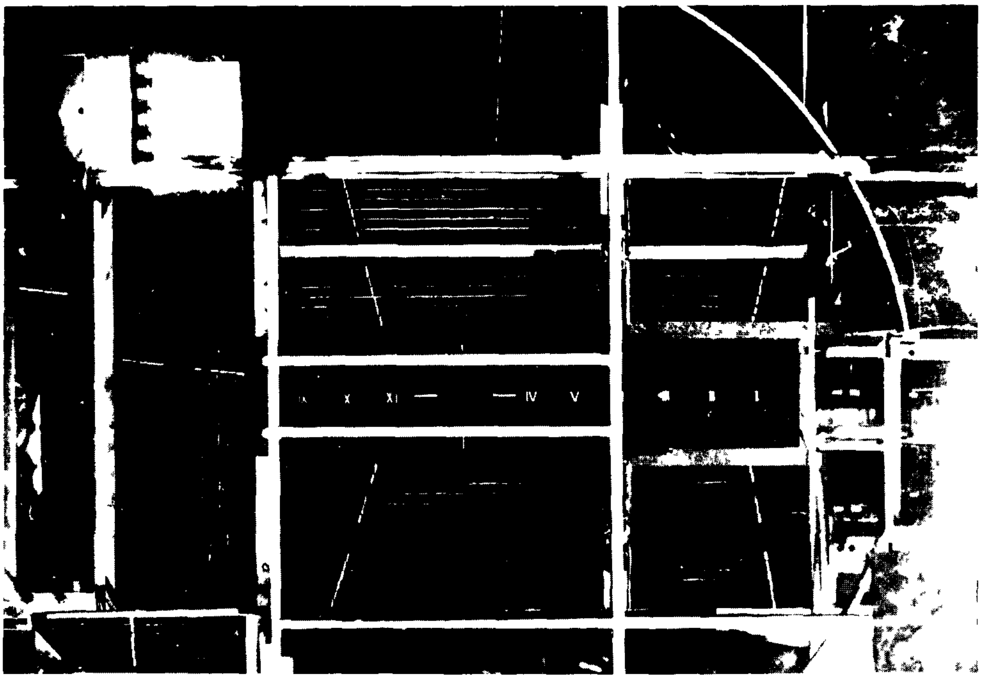

Fig. 2. An inelastic event showing how spaced spark chambers are useful in measuring angle by displacement.

---

[1] L. W. Jones, K. W. Lai, M. L. Perl, C. C. Ting, V. Cook, B. Cork and W. Holley, Proc. Int. Conf. on H. E. Phys., CERN 1962, p. 591

from the spherical lens, giving an image reduction on the film of about 30 1 Frames from the data film are shown in figs 2 and 3

A short experiment was performed at CERN by Bleuler *et al* [2]) wherein the peripheral production of pions by 12 and 17 GeV incident pions was studied Here four chambers were used one pair, spaced by one metre, ahead of a two-metre bending magnet, and the second pair, also spaced by one metre, behind the magnet For comparable resolution, these spacings corresponded to a one milliradian accuracy in bending angle through the magnet, or a one per cent measurement on 12 GeV/*c* particles The particular chambers used here were single-gap mesh-type chambers developed by Culligan *et al*[3]) While good date data were collected and events successfully analyzed from this run, the group found the identification of particle tracks in the mesh chamber photographs difficult This is primarily due to the fact that there is no redundancy in the information on a track contained in the data with these chambers, while on the other hand in multiplate chambers several sparks in a row leave no question as to the passage of a particle

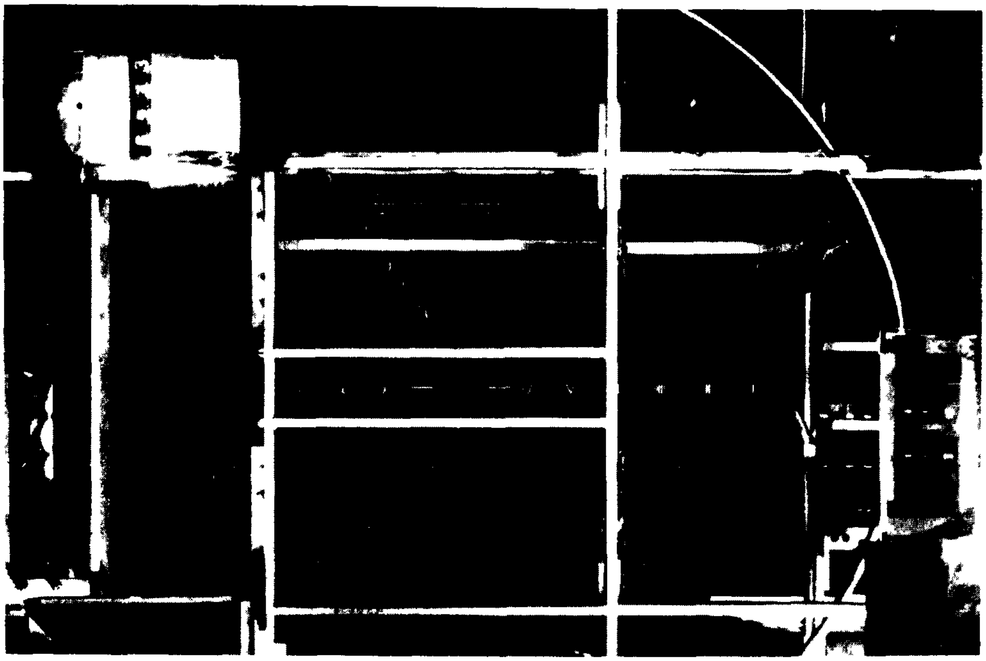

Fig 3 An elastic event

This experiment has now been rebuilt and test runs made using 9 parallel-plate chambers Two 2-metre bending magnets are used, one defining the incoming pion momentum and direction, the second to analyze the reaction products The system of spark chambers and magnets is indicated schematically in fig 4 Again mirrors (32) are used to image the chambers and their 90° stereo views onto one 35 mm film frame, using a 17 m focal distance and a 300 mm lens The light from each chamber is reflected by a 45° mirror directly above the

---

[2]) E Bleuler, D O Caldwell, B Elsner, L W Jones and B Zacharov, Proc Int Conf on H E Phys , CERN 1962,p 610

[3]) G Culligan, N Lipman and D Harting CERN Report 61 — 25, 1961

chamber to a horizontal path perpendicular to the beam axis Two subsequent vertical mirrors then direct the light near the optic axis of the camera The optical path lengths from each chamber (or spherical lens) to the camera are equal The five larger chambers (the largest 120 × 20 cm^2) employ spherical field lenses

Some tricks we have learned and special innovations in the experiments described above may be of interest In order to align the mirrors accurately, the auto-collimation principle is used A small plane mirror is located at the center of the field of view of each spark chamber, or group of chambers (as the case may be) and accurately levelled with a spirit level A theodolite (or transit) is located at the camera position and the mirrors adjusted, until the image of the theodolite is centered in the cross hairs This guarantees that the optical axis is normal to the horizontal plane at the chamber to a very good precision Then any spherical field lens used with this chamber (or chambers) is placed with its center along this axis We have used these lenses only with the larger chambers or groups of chambers more to render the light parallel and obviate the necessity for correcting apparent spark positions for depth in the chamber than for the usual reason of permitting viewing parallel to the plates With long focal distances and chambers of only 6—10 gaps, one can view between gaps of even a rather large chamber In our experiments the aperture of the spherical lenses has been about $f/10$ or greater, so it has been unnecessary to correct for spherical aberration

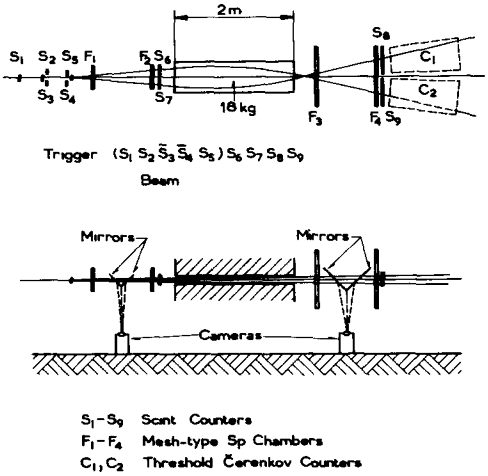

Fig 4 Plan and elevation view of the first version of the dipion experiment Only the pole-face area of the analyzing magnet is shown (2 meters by 55 cm)

We have used 90° stereo viewing in these experiments, and with only two views there can be concern over the stereo ambiguity in cases where two tracks completely traverse a chamber This has not been a problem in manual scanning, since usually at least one track shows some anomalous feature such as a delta ray, etc However, a simple solution was suggested to avoid taking a third view Thin plastic prisms may be affixed to one or two gaps of a chamber in one of its views so that the image of sparks from those gaps is displaced by an amount proportional to depth in the chamber from the extrapolated line through the other sparks The information derived in this way can more readily be used for resolving the stereo ambiguity by automatic measuring devices than the more subjective criteria of anomalous sparks As use may be made of a flying spot digitizer in the analysis of our current experiment, such prisms are being used

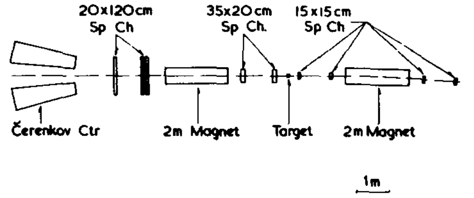

Fig 5 Plan view of the second version of the dipion experiment The spark chambers are all 6 gap except for the 35 × 20 cm^2 chambers which are 10 gap

Although not directly concerned with spark chambers as such, we are using two other new devices in the current experiment First, in order to distinguish pions from kaons as reaction products of the peripheral interaction, two large threshold Cherenkov counters have been built Each has a sensitive volume 2 m long by 40 cm square (front) tapering to 70 cm square (rear) A spherical mirror reflects Cherenkov light from high-energy pions passing through the length of the chamber to a single five-inch phototube By subtending a rather large solid angle, a large fraction of the reaction products are labelled (by indicator lights photographed with the spark chambers) as to whether they are pions or not Using an appropriate freon at atmospheric pressure, pions of 5 GeV count while 14 GeV kaons do not As the momentum of the particles is known from their spark chamber trajectories, the labelling can be used with maximum effectiveness, even though the entire momentum range is not covered By simply changing the freon, the threshold is shifted to a new value Operating the chambers at atmospheric pressure makes it possible to use a light, aluminium construction for the chamber body They are filled, as are the thin-walled spark chambers, by continuous gas flow

A second innovation carries over a trick from low-energy physics into this high-energy region The problem is that counters 5—7 m from the target are used to trigger the spark chambers for a particular class (at least two very high-momentum secondaries) of events in the target Since the target is only about 3 % of an interaction mean free path, pions passing through may make interactions in the air, in the chambers or in the counters themselves For these the solid angle subtended by the counters is much greater than from the target This gives rise to a very large number of false triggers, which reduces the efficiency of the experiment for collecting useful data We are making use of $\mathrm{d}E/\mathrm{d}x$ counters immediately behind the target to distinguish reactions where at least two minimum ionizing particles escaped the target in the forward direction As is well known, a single counter is very ineffective in distinguishing average energy loss due to the Landau spread in pulse height (energy loss) However, if three counters are used, and the discriminator input of each into a coincidence is set to about 1 5 times the average pulse height for a single minimum ionizing particle, the resulting system can be about one per cent efficient (or better) for counting a single minimum ionizing particle and more than 90 % efficient for detecting two or more particles (from a reaction) Preliminary tests have supported these predictions It should be noted that the proper operation of the system requires holding the phototube gain to about 10 %, and under high beam rates (of about one per microsecond) better-than-average dynode voltage stability is required to prevent a sag in output pulse height greater than this

In conclusion, we might again note that our use of spark chambers corresponds to a sampling of particle trajectories to obtain a maximum accuracy on track angles with a minimum of material and complexity This is in contrast to applications where an entire event is recorded as continuous tracks in chambers, as in a bubble chamber We believe that our technique can be usefully extended into many experiments in elastic and inelastic scattering, particularly at energies above 5 GeV

We would like to acknowledge the many ideas, designs, and other significant contributions to the work reported here In particular, we were taught spark chamber technique from K M Terwilliger, and D I Meyer K W Lai, D Daymouth, and O Haas contributed to the elastic scattering experiments at Berkeley, and important contributions to the CERN experiments were made by N Lipman, W Hoogland, H Kuhn, W Beck, S Sicher and B Smith

The elastic scattering experiment and work connected with it was supported by the U S Office of Naval Research