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Digitized Spark Chambers at BNL*

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Topics: New materials and scattering of printed planes, low mass wire planes, large size printed planes, pulsed electrodes with core readout, planes with 40 conductors/inch, operating characteristics, spatial and time resolution, applications and systems data, growth trends.

Introduction

Since the last Instrumentation Conference for High Energy Physics at Purdue about a year ago, digitized spark chambers¹ have come into wide use at Brookhaven. The combination of digitized spark planes and on-line computers has not only permitted the rapid kinematic analysis of particle interactions but has also given a running control over the experiments² by virtue of immediate playback. It is therefore not surprising that at Brookhaven National Laboratory the fourth system is already being assembled for an experiment this year. Some of the developments since the last conference are summarized in this paper.

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Construction, Reduction of Scattering

The "standard" planes are still of the printed circuit type with a 1/4" gap using Ne + 10% He + 1.5% ethyl alcohol with dc, and pulsed clearing fields¹ for rapid recovery after a spark. Since the beginning of 1966 all planes have both electrodes etched with conductors oriented at right angle to each other. The scattering mass of the planes has been reduced as follows:

<u>Construction</u>	<u>1965</u>	<u>1966</u>	<u>Low Mass</u>
Ground electrode	1.3 mil Cu 50% ¹⁾	.6 mil Cu 50%	2 mil S.S. 20/inch
Pulsed electrode	1.3 mil Cu 100%	.6 mil Cu 50%	2 mil S.S. 20/inch
Substrate	5 mil Fiberglass Epoxy	3 mil "H" Film	None
Windows	2 mil "Aclar"	1-2 mil "Aclar"	1/2 mil "Mylar" ²⁾
Approx. Air Equivalent Scattering Length	~ 150 cm	~ 60 cm	~ 6 cm

Notes: 1) Etched conductors 20 (or 40) per inch, 24 (or 12 mil) wide.

2) Window common with helium of beam transport.

The "standard plane" now scatters as 60 cm of air while the special low mass plane with electrodes of 96% transparency scatters only as 6 cm of air. It is employed in strategic locations for particles of relatively low momenta (see Fig. 5a).

Large Size Planes

Large printed planes now have an active area of 3 x 1 1/2 ft (6 x 2 ft types are in development). Two of these with 20 lines/inch are shown in Fig. 1; one features memory core readout, the other magnetostrictive pickup lines,³ the latter have both a receiver and a transmitter for serial connection of these lines. A new thyatron pulser with a delay of about 20 nsec was also developed for these large planes. The sparking efficiency of the large planes is about 99%. The average number of wires per spark is about 2 to 2.5. Recovery time is less than the usual one millisecond preset dead time.

Core Readout from Pulsed Electrode

In order to reduce the scattering material and the number of planes in the beam where two coordinate readouts are required, a readout from the pulsed electrode was provided. The spark wires on the memory core board of the pulsed plane are Teflon⁵ insulated to avoid sparking to the grounded read and sense wires. The cores used are Indiana General Corp. part No. MC142 (50 mil i.d.). The ground electrodes employ the smaller cores, part No. MC550 (30 mil i.d.), used in earlier readout systems.⁴ The upper part of Fig. 2 shows a completed plane with core boards on both electrodes. In medium sized planes the HV can be capacitor-coupled to the common spark wire bus on the core board.

Electrodes with 40 Conductors per Inch

The spatial resolution of the planes was improved by etching the electrodes with 40 conductors per inch instead of the usual 20 per inch. This permits better momentum resolution or larger solid angles in experiments.

The foreground of Fig. 2 shows an 18" x 6 1/2" electrode with 40 wires per inch. Alternate groups of 32 wires are emerging on either side via printed fanouts permitting the use of the "standard" 20 lines per inch core boards and readout programs. Planes of this type are now being made up to 3 ft long, i.e. 1440 lines. The finished plane in the back of Fig. 2 features 40 lines per inch in the ground electrode but only 20 lines per inch in the pulsed electrode as the resolution usually need not be as fine along the magnetic lines in spectrometer applications.

Plane Characteristics

In Fig. 3 on top are shown some of the characteristics of the two electrodes of the hybrid plane. The efficiency is the same for both, reaching 99% at 3200 volts. The number of wires per spark in the 40 per inch electrode is about 3 at the beginning of the plateau, i.e. double that of a comparable 20 per inch model. The pulsed electrode in the same region however averages only about 1.2 wires per spark, i.e. less than the expected half. This is partly

due to the direction of avalanche growth towards the positive ground electrode and partly due to the larger energy requirements of the bigger cores in the pulsed plane.

The lower part of Fig. 3 shows a spatial resolution curve obtained by measuring the deviation of sparks in the center plane using tracks traversing three planes spaced 6" apart. The full width at half maximum is about equal to one line spacing or 25 mil. It is about a factor of 1.8 better than in planes with 20 lines per inch (where multiple scattering of the particles can be neglected).

The resolving time for 1/4" gap planes in Ne + 10% He + 1.5% ethyl alcohol was investigated over a wide range by measuring the efficiency as a function of delay to the application of the high voltage at various clearing fields as shown in Fig. 4. The curves also indicate a non-monotonic electron disappearance effect described elsewhere.⁶

Applications to Experiments⁷

Four experimental systems and performance data are described in Fig. 5 in chronological order.

In 1965 the group headed by G. B. Collins at the AGS ran a p-p scattering experiment for production of isobars, utilizing 12 planes in a single spectrometer² layout of about 100 ft. The system

using core readout was on line to a PDP-6 computer and analyzed about 150 events per burst. It had a momentum resolution of about .6% (including the beam spread at 30 BeV/c).

In 1966 the group headed by H. Palevsky at the Cosmotron has been using a double spectrometer in coincidence for correlation experiments in studies of nuclear structure. The system utilizing core readout is linked to the Merlin computer. The slow event rate is limited by flux and background. The energy resolution, when utilizing some low mass planes, is .3% at 1 BeV. It is limited by scattering in the helium of the beam guide.

A third system, for a k-p back-scattering experiment by A. Lundby et al., is now in the test beam. It differs from the previous experiments in that it is compact and covers a wide solid angle. It also includes a spectrometer, thus permitting analysis of the complete interaction. Such analysis takes about half a second on the CDC-6600 utilizing the "GRIND" kinematic program from CERN. The system uses two-dimensional magnetostrictive readout of up to 4 particles per plane and is on line to a PDP-8.

The fourth system for a π -p scattering experiment for the production of isobars of G. B. Collins et al. is now being tested in part. It will feature a double spectrometer for the incident and scattered particles. The planes of up to 3 ft length will be of

the 40/20 lines per inch type including some with core-readout from the pulsed electrode. The system is expected to have a resolution of .5% and will be on line to a PDP-6. It will be more fully described by Bleser et al. at this conference.

Growth Trends

From the above one may discern a tendency to more complex systems as the devices become more familiar. Apparent is also a splitting into applications demanding high accuracy at small angles and those covering a large solid angle at lower resolution, with the recording and analysis of complete events, reminiscent of bubble chamber practice.

Some of the development trends in planes and systems are shown on a log scale in Fig. 6 for the period from 1963 and extrapolated to 1968.

If the past growth rate continues then the area of the largest plane in a system (now about 1 sq meter) may reach 10 square meters in 1968. The availability of large deflecting magnets for particles will be a factor in this case.

The number of measuring bins in a system, i.e. the sum of information channels along the coordinates of all planes, now about 10^4 , may reach 10^5 in 1968 (figuring two bins per wire spacing).

The computer analysis time per event will probably follow two levels. In relatively high cross section experiments it is likely to be kept below 100 msec of PDP-6 (or equivalent) time. In more complex geometry interactions the analysis time may grow to exceed one second of CDC-6600 time. However, as indicated on the event rate plot, interesting complex events tend to be rare. In high cross section experiments both the analysis time and the rate may increase. With either type of interaction, the total computer time may become a restraining factor.

References

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4. W. A. Higinbotham, J. F. Jacobs, H. R. Pate, IEEE Trans. Nucl. Sci., NS-12, No. 1, 386 (1965)
5. e.g. American Super Temperature Wires, Inc., Cat. No.: 32T 1/32
6. J. Fischer, Proceedings of the 7th International Conference on Phenomena in Ionized Gases, Belgrade (1965) (Also BNL 9443)
7. The planes and their characteristics were developed and tested by the author. However the data on the complete spectrometers in this section were supplied in part by the various groups as indicated. The data on the 4th experiment (G. B. Collins et al.) is tentative only.

Figure Captions

- Fig. 1   Two 3 x 1 1/2 ft printed planes; the one on the left with core readout, the other magnetostrictive readout.
- Fig. 2   Front: 18" electrode with 40 lines/inch.
Rear: Hybrid plane: 40/inch ground electrode, 20 per inch pulsed electrode, core readout from both electrodes.
- Fig. 3   Top: Hybrid plane characteristics.
Bottom: Spatial resolution test using three planes with 40 lines per inch.
- Fig. 4   Resolving time curves. Sparking efficiency vs total delay at various drift fields.
- Fig. 5 a and b   Four digitized spark chamber experiments and comparative systems data.
- Fig. 6   Growth trends of planes, recording systems, event analysis time, and event rates.

FIGURE 1

FIGURE 2

FIGURE 3

SPARKING EFFICIENCY VS. DELAY TO HIGH VOLTAGE PULSE

GAP 1/4" ; NEON + 10% He + 12 mm Hg C₂H₅OH, P = 760 mm Hg
SPARK PULSE : - 4.5 KV OPPOSING D.C. CLEARING FIELD

FIGURE 4

1965

G.B. COLLINS et.al. at A.G.S.

20 LINES / INCH; DEADTIME SET: ~ 1 msec.
 READOUT: CORES, BUFFER MEMORY, MAGNETIC TAPE.
 COMPUTER: PDP-6 ON LINE.
 DATA RATE: ~ 150 EVENTS / BURST; $\sim$ EVERY 2 sec.
 ANALYSIS TIME: ~ 15 msec / EVENT.
 ANG. RESOL. $\approx .3$ mrad (SYSTEM) AT 30 BeV/c (70 mrad)
 $\frac{\Delta P}{P} \approx .4\%$ SYSTEM; $.6\%$ (INCLUDING BEAM SPREAD)

1966

H. PALEVSKY et.al. at COSMOTRON

20 LINES / INCH; DEADTIME SET: ~ 1 msec.
 READOUT: CORES, BUFFER MEMORY, MAGNETIC TAPE.
 COMPUTER: "MERLIN" ON LINE.
 DATA RATE: SINGLE SPECTR. ~ 100 / BURST
 DOUBLE SPECTR. ≈ 1 / BURST.
 ANALYSIS TIME: SINGLE: 30 msec; DOUBLE: ~ 60 msec / EVENT.
 $\frac{\Delta E}{E} \approx .3\%$ AT 1 BeV (INCL. $.25\%$ IN HELIUM OF BEAM TRANSPORT)

FIGURE 5 a

1966 - (1967)

$k^\pm + p \rightarrow p + k^\pm$ (backward)

A. LUNDBY et.al. at A.G.S.

20 LINES/INCH; MAGNETO STRICTIVE SERIAL READOUT
 ~ 2.5 msec., UP TO 4 PARTICLES PER PLANE.
 PDP-8 ON LINE, CDC-6600 OFF LINE (OR TIME SHARE)
 EXPECT. DATA RATE: $\approx 5-30$ /BURST, (INCLUDING $\pi + p$, etc)
 COMPLETE ANALYSIS TIME: $\approx .5$ sec./EVENT ("GRIND" PROGRAM)
 ANG. RESOL. $\approx 1^\circ$ (LTD. BY SCATTER IN H_2), $\frac{\Delta P}{P} \approx 5\%$

(1966) - 1967

$\pi^- + p \rightarrow \pi^- + N^*$

G.B. COLLINS et.al. at A.G.S.

40 LINES/INCH - X; 20 LINES/INCH - Y
 READOUT: CORES, BUFFER MEMORY, MAGNETIC TAPE.
 PDP-6 ON LINE, + CDC-6600 OFF LINE.
 ANALYSIS TIME: $\approx (40 \text{ msec} + 5 \text{ msec})$ / EVENT
 EXPECT. DATA RATE ≤ 200 EVENTS / BURST.
 $\frac{\Delta P}{P} \approx .5\%$ AT 20 BeV

FIGURE 5b

FIGURE 6