WIRE SPARK CHAMBER DESIGN AND PERFORMANCE USING FET, CAPACITOR READOUT*

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1. Introduction

The continuing motivation for this readout system is its high sensitivity and its immunity to magnetic fields. Readout sensitivity is necessary for two reasons; first for good multiple spark efficiency; and second to keep the level of ionization within the spark chamber low in order to reduce the possibility of refiring on old tracks when operating at high spark rates.

We operate these chambers with high voltage driving pulses having a decay time constant of 90 n sec., and under these conditions the level of ionization in the spark is 10^{-7} to 10^{-6} coulombs. This level of ionization is considerably lower than that required by other currently used types of readouts, and corresponds to a gas gain of the order of 10^{10} to 10^{11}. Gas gains of 10^{7} would be enough for efficient readout, however we have not obtained good chamber efficiency at this low a gas gain. Possibly shorter high voltage driving pulses or other gases would be more suitable.

2. Chamber Construction

The chambers have three electrodes; the center electrode has an aluminum foil pulse electrode 0.0005 inches thick,

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while the outside electrodes form and X and Y readout grid of 0.0004 inch diameter copper wire. The wire spacing of the readout grids is 1 mm, and the spark gap is 10 mm. The readout wires are soldered to a printed board which has a 72 pin connector for each group of 32 readout wires. The remaining connector pins are used for the readout of data. This printed board and its connectors are a permanent part of the spark chamber, while the data memory cards, which carry all the active circuit components are plug-in's.

Presently three functionally identical data memory cards are being used; they differ only in physical size. Card number 1, Figure 1, is made with standard discrete components and measures 15 cm x 13 cm and is about 1.5 cm thick. Card number 2 is also made with discrete components; however it has been made from four small boards joined to a common connection board. Its size is 9.5 cm x 8.2 cm and is 3 cm thick. Card number 3 uses a special hybrid circuit made for us by the Burroughs Corp. and a discrete RC filter network; it measures 10 cm x 9 cm and is 1.5 cm thick. We hope to design a new hybrid card that will be considerably smaller than any of our present cards.

It is worth noting that the electronic volume would be reduced considerably by reducing the wires handled per card from the present 32 wires to 16 wires, however our present design may be used with a wire spacing of 48 wires per inch provided the thickness of the data memory card is kept below 1.6 cm.

3. The Basic Circuit and its Operation

The capacitor memory FET switch circuit is shown in Figure 2. This circuit is similar to the original circuit proposed in 1968[1]; the differences are the use of a clamp diode (for cost reasons only) instead of a zener diode, along with an additional RC network between the spark chamber wire and the memory capacitor. The function of this additional RC network is to reduce the magnitude of the transient current through the clamp diode. This in turn reduces the peak transient voltage across the FET. The gate resistor of the FET allows an N channel FET to gate negative signals and assures a fail safe situation, i.e. should a gate short occur in the FET the drive voltage to the other 31 common circuits will not be effected. The 150 ohm resistor in series with the FET discharge path improves its transient voltage tolerance from roughly 70 to 300 volts.

As with magnetic core readout a quenching agent in the gas is needed to prevent spark current ringing. We use a standard gas mixture of 90% Ne, 10% He with one half the gas passed through an ice bath of I Proponal alcohol. If more alcohol than this is used one observes widening of the discharge on the anode wires.

The data scanning is organized to readout 32 wires at a time, and scanning proceeds at a 1 mHz rate until data is found. The address of the spark and its width are determined by the data scanner and sent to an on-line computer or buffer memory. After all the data has been transferred the scanner goes into a continuous erase mode, in order to keep all the memory capacitors completely discharged until the next event is found. The scanner is connected to the spark chambers by 6 m long cables as it is desirable to keep the readout electronics out of the magnet; however all scanner controls and indicator lamps are in a remote control box which may be located at any convenient location. All electrical connections between the spark chamber and the scanner are through transformers to assure freedom from ground currents.

4. Performance

Three 25 cm x 25 cm chambers with a total of 1,500 wires readout have been tested with cosmic rays and operated in a proton beam at the University of Chicago's Cyclotron. Spatial resolution, Figure 3, of less than one mm FWHM was observed by comparing one chamber against the other two, and we conclude that the spatial resolution of these chambers is identical to that obtainable with magnetic core read-out chambers. The spread, i.e. the number of adjacent wires that fire, varies between 2 and 5 and may be controlled by the high voltage pulse width and magnitude. The high voltage pulse used to drive the chambers is around 4.5 K.V. at the chamber and has a 90 n sec. decay time constant. Efficiencies of better than 99% are readily obtained.

During the course of these tests roughly 30 x 10^6 individual sparks have been produced, and during this time 4 FET's have become leaky and required replacement. Components were not pretested.

These chambers, shown in figure 4, were used to measure efficiency and spatial resolution of some of our film supported wire proportional chambers; during the course of these tests we learned to appreciate their low level of noise as our proportional chamber was only 25 cm from the spark chamber.

5. Acknowledgment

We would like to thank Professor H.L. Anderson for his interest and support of this work, and D. Jensen for his programming effort that made the final testing possible.

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REFERENCES

1) IEEE Transactions on Nuclear Science June, 1968, Vol. N5-15, November 3. "A High Sensitivity Wire Spark Chamber Readout Useful in Strong Magnetic Fields", M. Neumann T.A. Nunamaker.

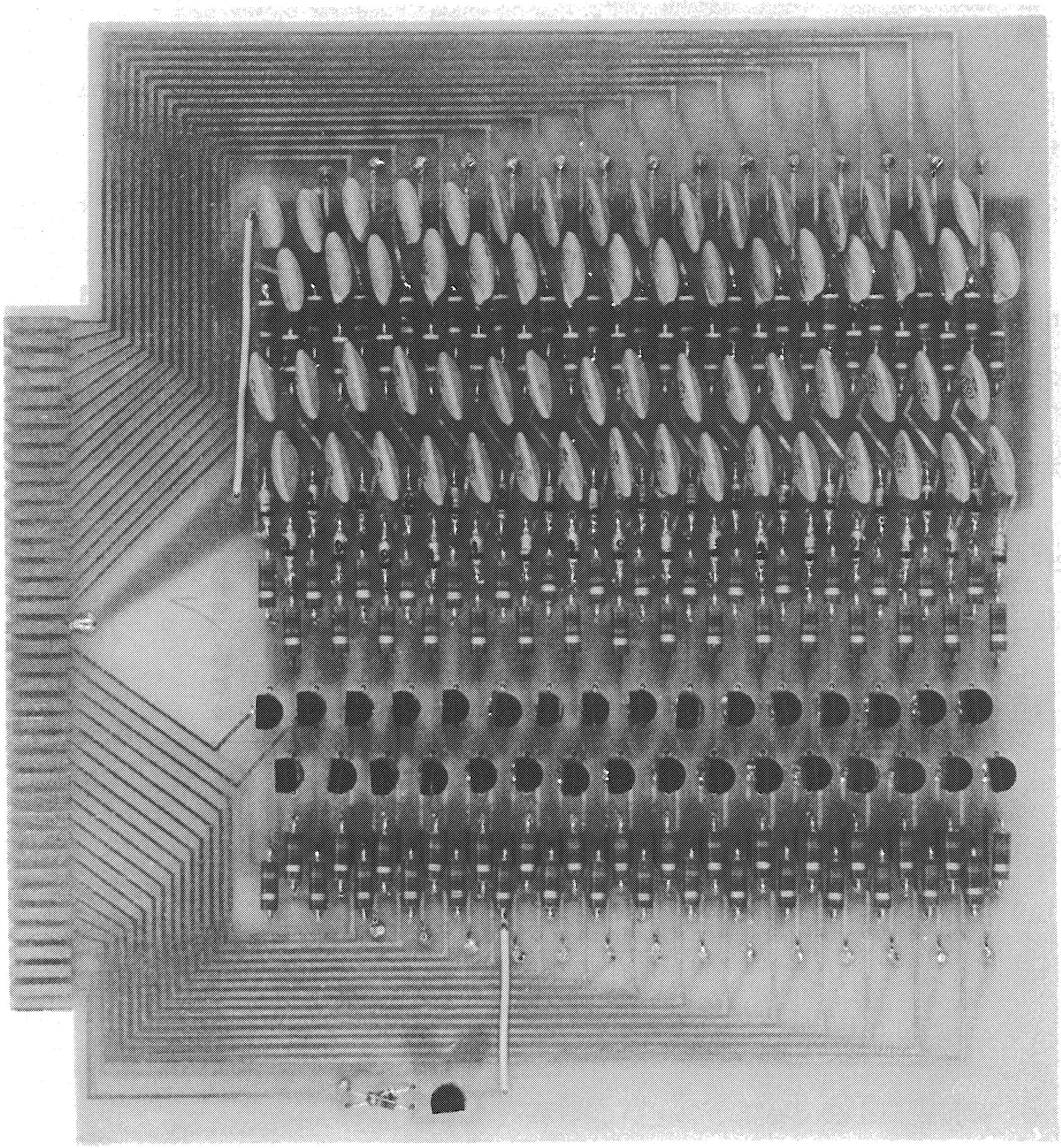
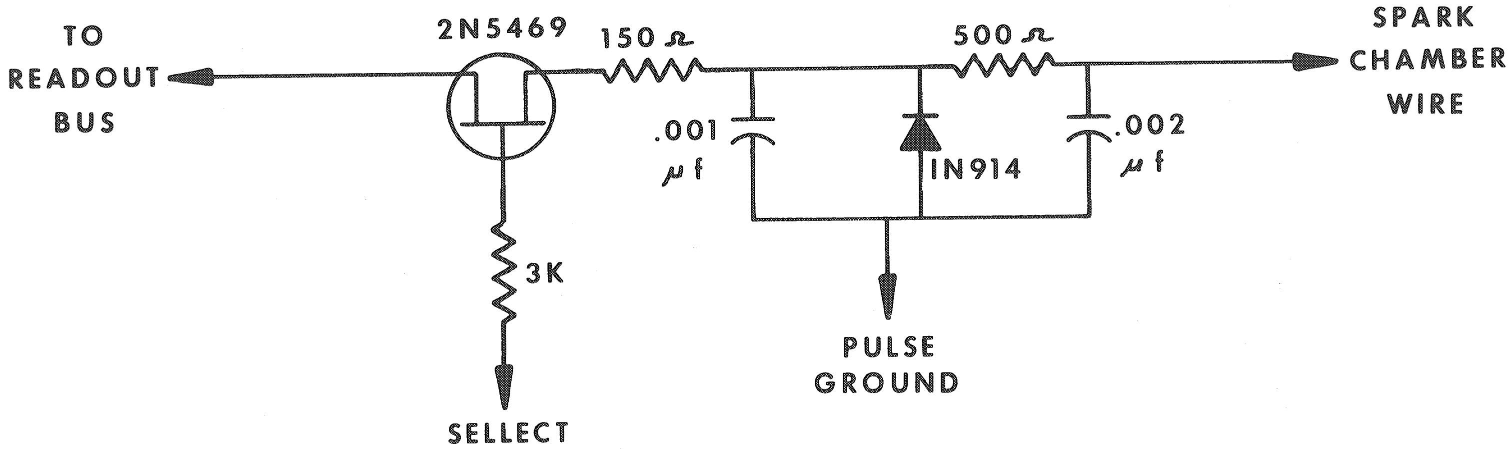


Fig. 1 Data memory card



F.E.T. READOUT CIRCUIT

Fig. 2 Memory circuit

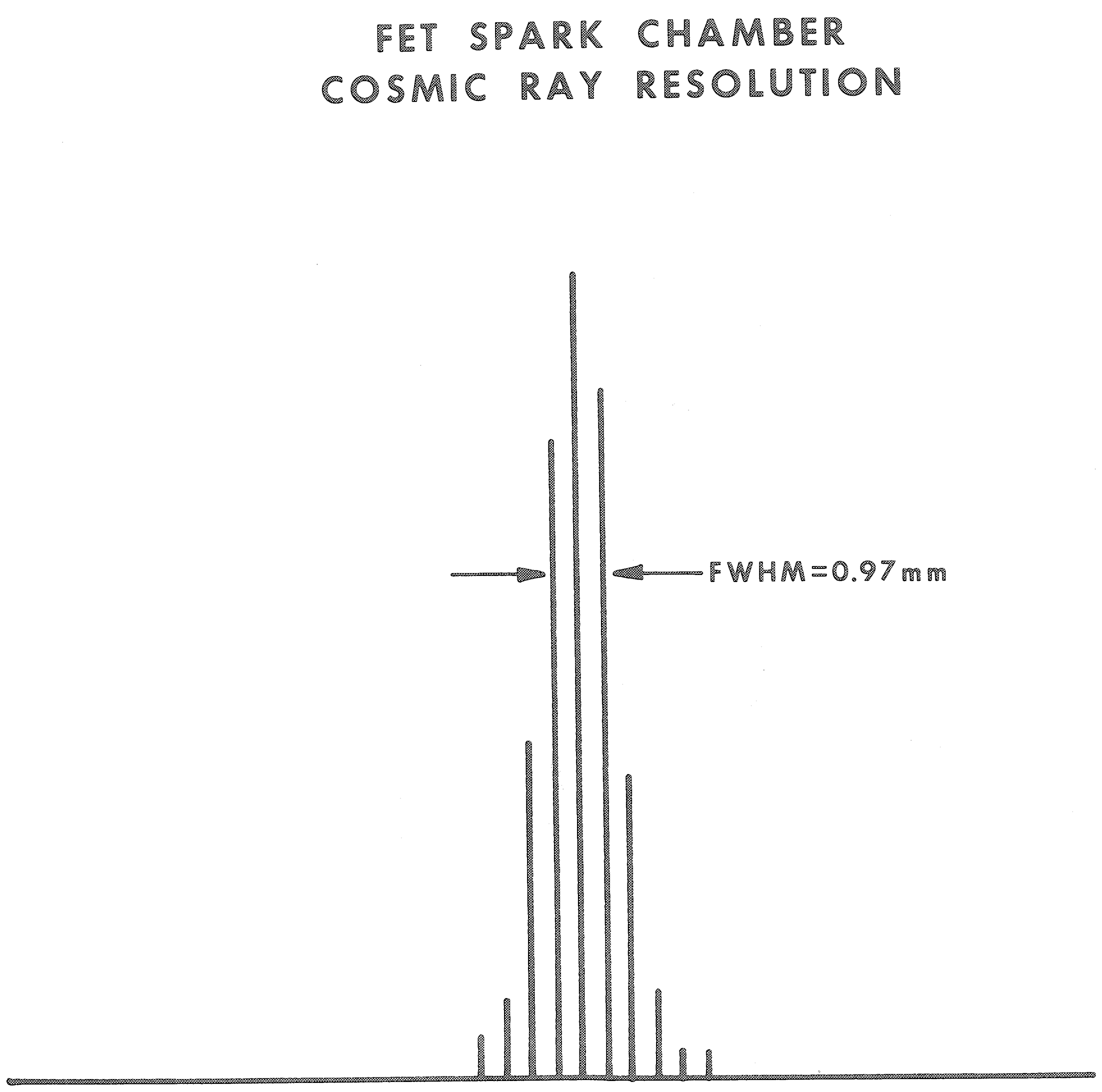


Fig. 3 Cosmic ray resolution

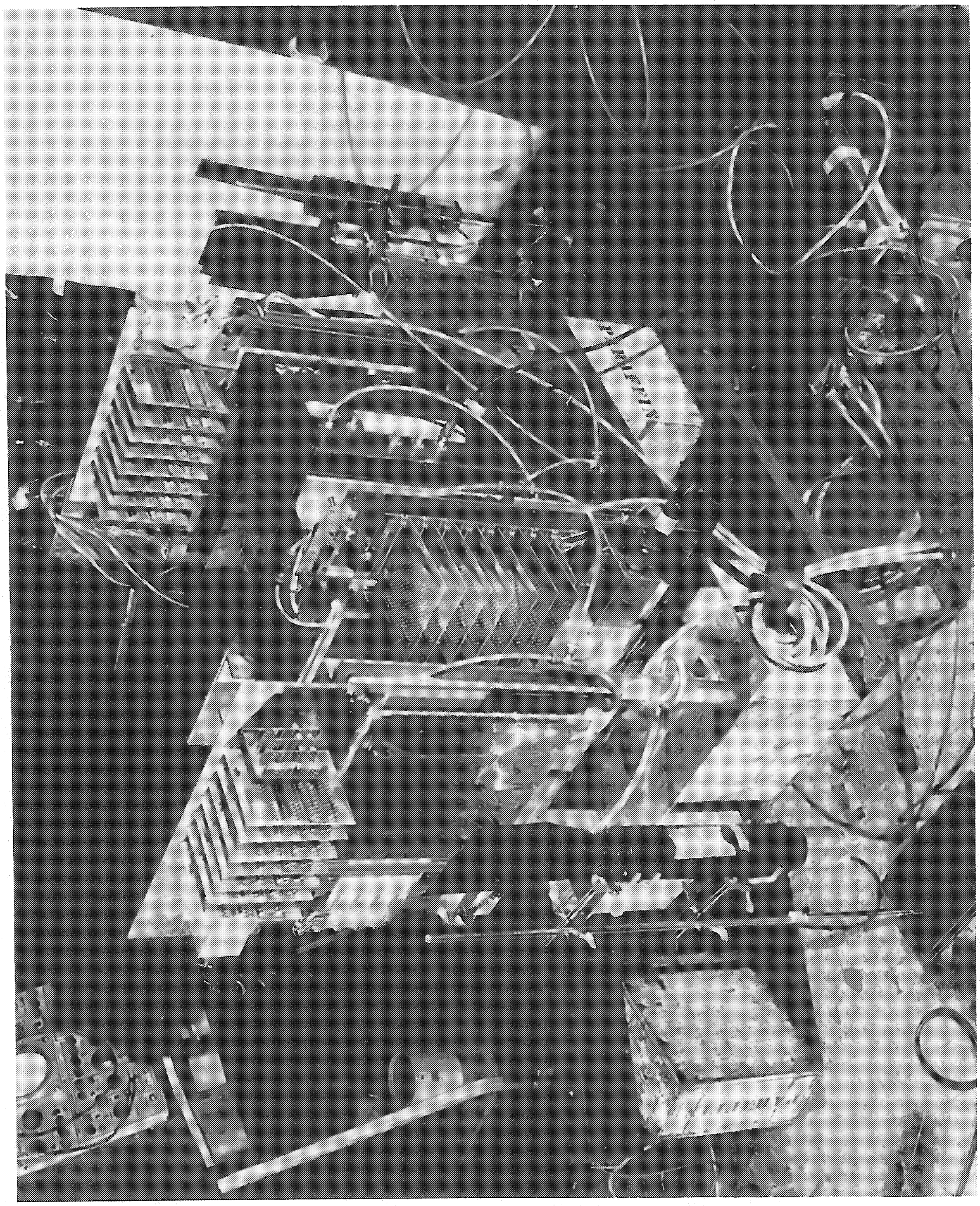


Fig. 4 3-chamber spectrometer

DISCUSSION

P. OSMAN *(Westfield College)*: How does the cost of capacitative read-out compare with the cost of core read-out?

R. WINSTON: It is almost identical. Right now it may be about 20% to 30% higher, but by using hybrid circuits it becomes quite comparable, about $1 per wire.

H. GROTE *(CERN)*: Do you intend to build bigger chambers, and if so which problems do you foresee?

R. WINSTON: That is a question of the sort of physics one wants to do with these chambers, and right now I do not know of any specific experiment for them. This method was simply developed to see if it would work.

G. JARLSKOG *(Lund)*: Your statement of needing a 1 cm plane spacing for the Charpak chamber is clearly dependent on your choice of gas mixture.

R. WINSTON: Yes, the statement is true for the standard He-Ne at normal pressure and temperature. Certainly one can go to a different mixture or higher pressure, but that makes life hard.

H. FAISSNER *(Aachen)*: I would like to amplify on your remark about the connection between wire separation and resolution. You can do better than the value of $a/2$ which you quoted, if you run the chamber under the following conditions; Whenever a particle passes within $\pm a/4$ of a wire, just that wire fires and if it passes to within $\pm a/4$ from the centre between two wires, both wires fire. If one then assigns to one-wire events the wire position, and to two-wire events the centre position, the maximum error is clearly $\pm a/4$. In practice things are slightly worse, mainly because of the finite extent of the discharge but we have experimentally achieved a resolution of $a/3$.

E. QUERCIGH *(CERN)*: Are you sure that the idea of using a capacitative memory for spark chambers is only two years old?

R. WINSTON: The idea to use a capacitative memory is older, but how to do it practically, using a field effect transistor, is two years old. One needed a high impedance switch.