HIGH-RESOLUTION DETECTORS AT NAL

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ABSTRACT

A detector development program has started at NAL. High-resolution multiwire proportional chambers and spark chambers are being developed.

At NAL energies secondary particles from interactions will be produced at very small forward angles. Thus, spectrometer experiments to be done at momenta between 100-500 BeV/c are going to require either high spatial resolution detectors or very large detectors at large distances from the analyzing magnets. Such large spectrometers are rather costly, and production of large detectors (proportional chambers, spark chambers, etc.) and large magnets with uniform fields is difficult. Detecting short-lived particles before they decay also demands high spatial resolution detectors. High-resolution detectors will also shorten the overall dimensions of an experimental arrangement and, therefore, will reduce the multiple Coulomb scattering. With the hope of helping NAL's future experimental program, a detector development program has been started. In this report we will discuss the type of detectors and some of the results. Our present detector development program consists of:

1. high spatial resolution multiwire proportional chambers,
2. high spatial resolution wire spark chambers.

High Spatial Resolution Multiwire Proportional Chambers

Multiwire proportional chambers may extensively be used in future high-energy particle experiments. Many of the proposals submitted to NAL support this statement. The main advantages of this type of detector over the conventional spark chamber are the ability of counting 10^6 particles per wire per second, good time resolution (typically ±15 nsec at fwhm), good performance in magnetic fields, and providing high multiparticle detection efficiency with minimal multiple scattering.

Multiwire proportional chambers with 1 mm and 0.5 mm wire spacing have been built at NAL.[1] Summarized below are some of the results obtained from the 1 mm wire spaced chamber:

1. Chamber efficiency above 99%,
2. Gas multiplication factor of > 10^5,

3. Single chamber spatial resolution of ± 0.5 mm,

4. Time resolution of ± 15 nsec at fwhm,

5. Probability of having two simultaneous pulses on two adjacent wires of about 2% and on three adjacent wires of less than 0.1%.

The multiwire proportional chamber with 0.5 mm wire spacing and about 4×4 cm^2 sensitive area is being tested at NAL. For the tests a Ru^{106} β-source ($E_{max} = 3.5$ MeV) is used. A simplified cross sectional diagram of the chamber is shown in Fig. 1. HV1 = 1500 V and HV2 = 3300 V potentials are applied to the 0.5 mm and 3 mm gaps between the wire plane and the cathode foils. The preliminary tests have produced satisfactory results. Pulses of 6 nsec rise time with 200 nsec fwhm are obtained across 6.8 kΩ resistors. More tests with this chamber using various gas mixtures and gaps will be performed at Argonne National Laboratory. We hope to obtain ± 0.25 mm single chamber spatial resolution from this detector.

Certain difficulties may limit the size of high-resolution proportional chambers. Mainly, these are the construction difficulties of a large chamber[2] and packing of readout electronics. The complexity and the cost of the amplifier and readout systems has limited the use of the proportional chambers in high-energy particle detection. The present cost of the complete IC readout electronics is about \$15-20 per wire. This is less than one-tenth of the cost of a scintillation detector. Therefore, it may be advantageous to use a proportional chamber as a hodoscope where 30 nsec time resolution is sufficient.

Efforts have been made to decrease the cost of the readout system by various groups. Recently, Perez-Mendez has reported[3] that 0.3 mm spatial resolution may be obtained from a delay line of 80 nsec/cm with a minimal cost of \$0.50 per wire. F. A. Kirsten has a readout scheme[4] for this delay line. This scheme is identical to the present magnetostrictive readout system of wire spark chambers. The disadvantages of this readout system are that the good time resolution obtained from a proportional chamber is sacrificed and the spatial resolution is very much pulse-height dependent; thus, the chamber can no longer be used as a trigger detector.

Stephen E. Derenzo[5] recommends an inexpensive readout scheme to be used for their high-resolution liquid-argon proportional chamber. This scheme uses Self-Scanned Linear Photodiode Array which is developed by Fairchild (FPA600). The main disadvantage of this scheme is that the time resolution is poor, 1 nsec per diode.

I believe that complete electronic readout[1,6,7] using integrated circuits (IC) is favorable. The cost of IC is going down. We hope that the cost and the dimensions of the rather complex electronic circuits may be reduced by having monolithic or hybrid integrated circuits. A. Minten (CERN), H. Steiner (LRL), G. C. Bolon and R. C. Lanza (MIT), M. Atac (NAL), and R. Larsen and J. L. Pellegrin (SLAC) have met to agree on a logic scheme. It is our hope that we can find a company that will produce our custom-made IC's.

High Spatial Resolution Wire Spark Chambers at High Gas Densities

Very recently, W. Willis has reported[8] that better than 75 μm spatial resolution is obtained with wire spark chambers operating at 15 atm pressure using neon-helium gas mixture. This is about a factor of four improvement relative to our 0.5 mm wire spaced, 3/8-in. gap, magnetostrictive readout spark chamber operating at atmospheric pressure.

W. Willis shows that the width of the spark column and plasma instabilities are reduced with narrow gap spark chamber operating at high pressures (see Fig. 2). The diffusion of the primary electron falls as the inverse square root of the gas pressure. This may be the main contribution to the improved spatial resolution. With high current density, thin sparks are then detected by printed circuit-type wire strips. The wire plane contains 200 strips per inch of 4×4 cm^2 area. The width of the Cu strip is about 63 μm and with the thickness of 10 μm. These wire strips are fanned out to 0.5 mm spacing where the spark current is magnetostrictively picked up. This time scale expansion of factor of four then enables us to use commercially available slow clock rate magnetostrictive readout systems without effecting the good spatial resolution provided by the spark chamber.

Knowing the above result, I have done preliminary tests in keeping the same wire plane at liquid nitrogen vapor temperature. Chamber was sparked at this temperature with 90% Ne and 10% He gas mixture and observed about 300 nsec width of sonic pulses. This would correspond to the chamber operation at 4 atm pressure at room temperature and about 100 μm spatial resolution. We are encouraged with the results and are planning to do more tests with wound wire planes and printed circuit planes of larger areas.

A simple styrofoam cryostat of 50 mg/cm^2 window wall thickness can provide the cooling for the spark chambers. Advantages of the low-temperature operation may be: smaller wire diameter because of lower ohmic resistance and thinner gas enclosure (mylar, kapton, etc.) because of nonexistence of water vapor at such temperatures.

REFERENCES

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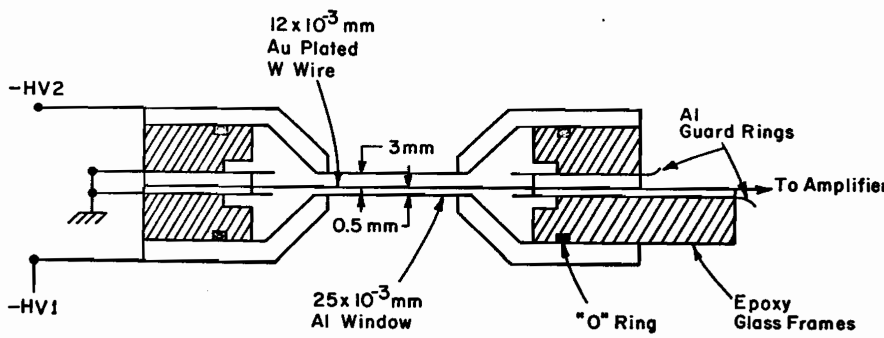

Fig. 1. Cross section of a multiwire proportional chamber.

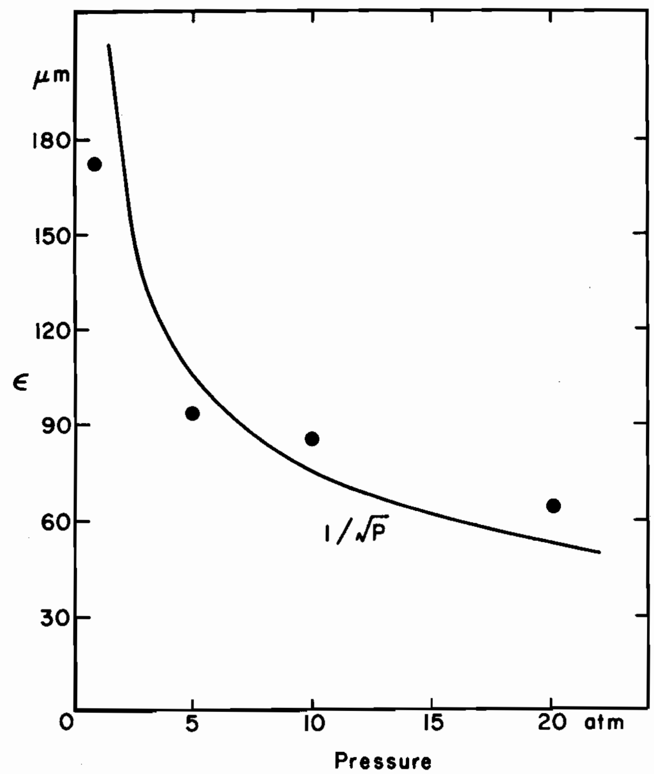

Fig. 2. Spark-column width as a function of pressure in a wire spark chamber.