Title
CYLINDRICAL GEOMETRY FOR PROPORTIONAL and DRIFT CHAMBERS

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CYLINDRICAL GEOMETRY FOR PROPORTIONAL AND DRIFT CHAMBERS

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1. Introduction

For experiments performed around storage rings such as e^+e^- rings or the ISR pp rings, cylindrical wire chambers are very attractive. They surround the beam pipe completely without any dead region in the azimuth, and fit well with the geometry of events where particles are more or less spherically produced. Also, such chambers are interesting devices around a target in conventional accelerator experiments.

Unfortunately, cylindrical proportional or drift chambers are difficult to make. Among the various questions to answer are:

a) How do you maintain the cylindricity of the chambers, or more specifically, the constancy of the gap?

b) How do you read the longitudinal coordinate? Note that usually a resolution of ± 1 cm is sufficient.

c) How do you minimize the amount of matter in the way of the particles?

d) How do you design an easily dismountable structure?

Through the various attempts to solve these problems, two approaches have emerged according to the way the cathodes are made: the wire technique and the styrofoam technique.

1.1 Wire Technique

The cathodes are made of wires stretched along the axis of the cylinder making it easy to maintain a constant gap [problem a)]; but problem b) of the longitudinal coordinate z is more difficult. Two solutions have been proposed: either rotate the end rings of the chambers slightly, getting a hyperbolic chamber and measure z by stereoscopy (JINR, DESY[1]), or wind a cathode wire in a helix pattern around a cylindrical structure of fiber glass wires (ORSAY[2]). The main drawback of the wire technique is that you do not have a self-supporting structure. Since the use of internal supporting rods cancels the main advantage of cylindrical geometry (no edge), the wire tension has to be transferred to a cylindrical frame outside the set of chambers. We have then an intricate system where changing a wire is very difficult. The main advantage, of course, is that the amount of multiple scattering in the chamber can be reduced considerably.

1.2 Styrofoam Technique

A sandwich of Mylar and styrofoam is used to provide an easily handled, self-supporting shell on which cathode strips can be printed. Problem b) of reading the longitudinal coordinate is solved automatically for proportional chambers and drift chambers without field shaping (Walenta's scheme[3,4,5]). We think that, by proper construction, problem a) (the constancy of the gap) can be solved, and the amount of matter in the way of particles can be kept reasonably small. We believe that 0.4% of one radiation length per chamber can be achieved with this technique. It is not much more than what is usually achieved with the wire technique, since in order to get z and y information, two hyperbolic chambers have to be used, and four layers of 120μ Molybdenium wires spaced at 2mm represent 0.23% of one radiation length. On the other hand, other techniques based on fiberglass self-supporting cylinders, as described by Timm and Walenta[6] at this conference, lead to much more material.

We have worked at Berkeley on the styrofoam technique and I would like to present to you:

- What we have realized: Two cylindrical proportional chambers operating quite well at SPEAR even at a few Megacycles continuous rate.

• What our plans are: We are building a large cylindrical drift chamber (90 cm diameter, 1.54 m long with two gaps) in order to test the feasibility of very high spatial resolution of the order of $\sigma = \pm 100\,\mu$.

2. Cylindrical Proportional Chambers at SPEAR

These two chambers (Figs. 1, 2) have been built for the magnetic detector of the LBL-SLAC collaboration at SPEAR. In order not to capture the beam pipe, which cannot be removed easily in our case, the chambers are made of half cylinders which are latched in place so that each chamber has a unique gas volume. The parameters are given in Table I.

Each half chamber has 32 cathode strips separated by 2 mm. They are perpendicular to the axis of the cylinder.

2.1 Construction Stages

Since the difficulty of building cylindrical proportional chambers lies in mechanics, it may be useful to enter into construction details. It may prevent your making the same mistakes we made.

2.1.1 Preparation of electrodes

a) We start with a sandwich of 25μ Aluminum and 125μ Mylar[7].

b) We etch strips. It is important to use an automatic etching machine where the bath temperature is kept constant.

c) We connect the strips to connectors. After many unsuccessful attempts, we used the following method: on the Mylar side of the Alu-Mylar sandwich, we strip off the aluminum with a soldering iron, dissolve the remaining glue with xylene, and solder a thin insulated wire.

2.1.2 Construction of the styrofoam[8] shell

a) After sawing a rough outline of a shell, we sandpaper it down to required dimensions on a lathe (Fig. 3). We used thicknesses between 8 and 20 mm.

b) We then glue the Alu-Mylar sandwich as follows (Fig. 4): one of the surfaces of the shell has to be of good quality since it is a cathode. Assume

Fig. 1. View of the biggest chamber.

TABLE I. SPEAR Cylindrical M.P.C. Parameters

	Chamber No. 1	Chamber No. 2
Radius at wires	173.1 mm	224.09 mm
Wire space	2.125 mm	2.75 mm
Number of wires	512	512
Wire diameter	.020 mm	.020 mm
Cathode strip width	1[illegible].[illegible] mm	23.4 mm
Space between cathode strips	2 mm	2 mm
Number of cathodes	32 × 2	32 × 2
Active length	508 mm	812.8 mm
Cathode to wire distance	8 mm	8 mm

Material	Thickness in Active length	Percent X_o
Styrofoam	19.1 mm	11×10^{-4}
Mylar	.35 mm	12×10^{-4}
Aluminum	.101 mm	12×10^{-4}
Glue	.25 mm	8×10^{-4}
Total X_o		4.3×10^{-3}

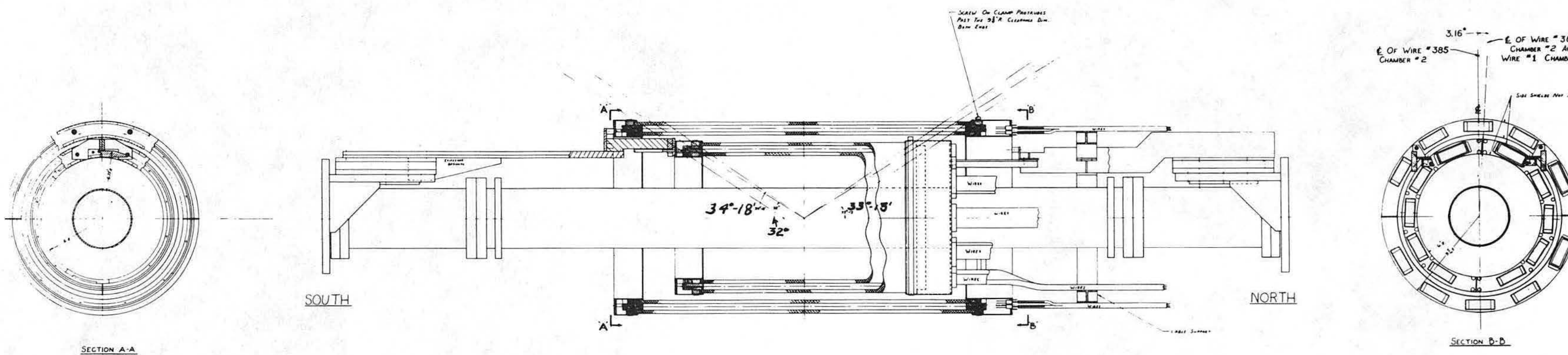

Fig. 2. Installation of the chambers around the SPEAR beam pipe.

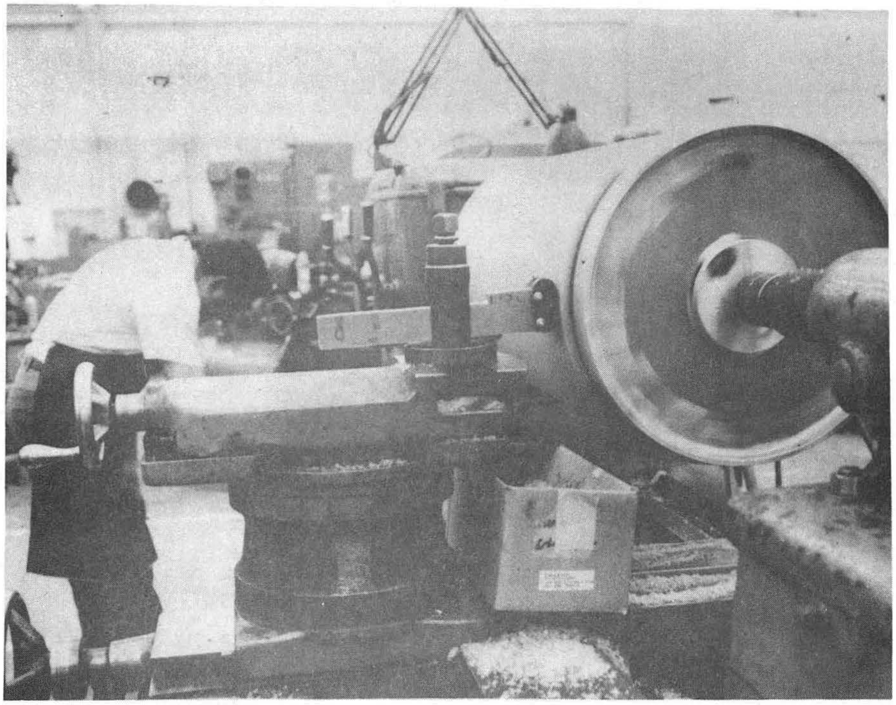

Fig. 3. Machining of the styrofoam shell.

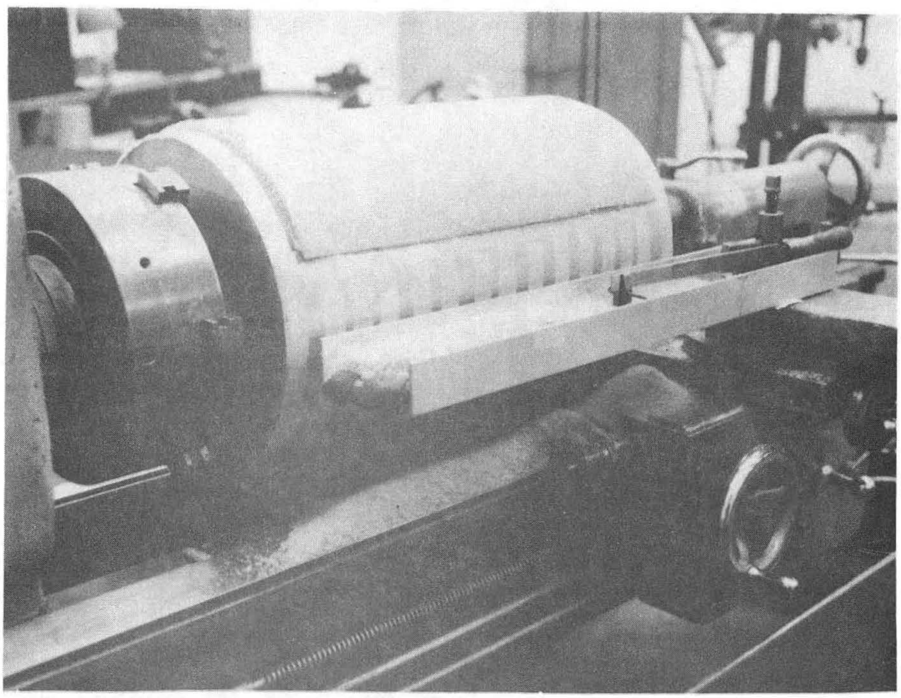

Fig. 4. Gluing of cathode on styrofoam shell.

that it is inside of a shell — we begin by vacuuming down the Alu-Mylar sandwich on a well machined drum. We put on a thin layer of epoxy and apply the styrofoam shell. After the glue sets, we cover the styrofoam with another sheet of Alu-Mylar on which we have applied a thin layer of epoxy. We apply vacuum to the styrofoam in order to suck down the mylar.

After setting we get a very rigid structure. For a complete cylinder of 30 cm diameter and about 50 cm long, the variation of diameter was of the order of ± 30μ. Such a shell can support 150 kg without any damage.

NOTE: We have also developed two other techniques:

- For large radii, we use a "tiling" technique, where instead of using a pre-formed cylinder, we use flat plates of styrofoam about 5 mm thick which we bend at the gluing stage.
- If both surfaces have to be used as a cathode, the above technique is not so practical, and we have to pour styrofoam in a mold on which the Alu-Mylar sandwich has been laid.

2.1.3 End rings

In order to support the printed board on which the wires are soldered and to improve the stability of the styrofoam shells, we have rather massive end rings machined out of fiber glass epoxy compound (NEMA-G 10). Figure 5 shows the gluing operation of the end rings on one shell.

An important characteristic is that wires are maintained in place by grooves machined in these end rings. It proved very useful when wiring the chambers (Fig. 6). This method is very similar to the one used by Kravchuk et al/1/ or W. W. Allison/9/.

2.1.4 Sealing

Once the chambers are wired, the two shells of half chambers are latched together to form a complete gas volume. The latching system of dovetail type is supported by two L-shaped pieces (Fig. 7a). This assembly is made leak proof with a rubber foam gasket; we had no problem there.

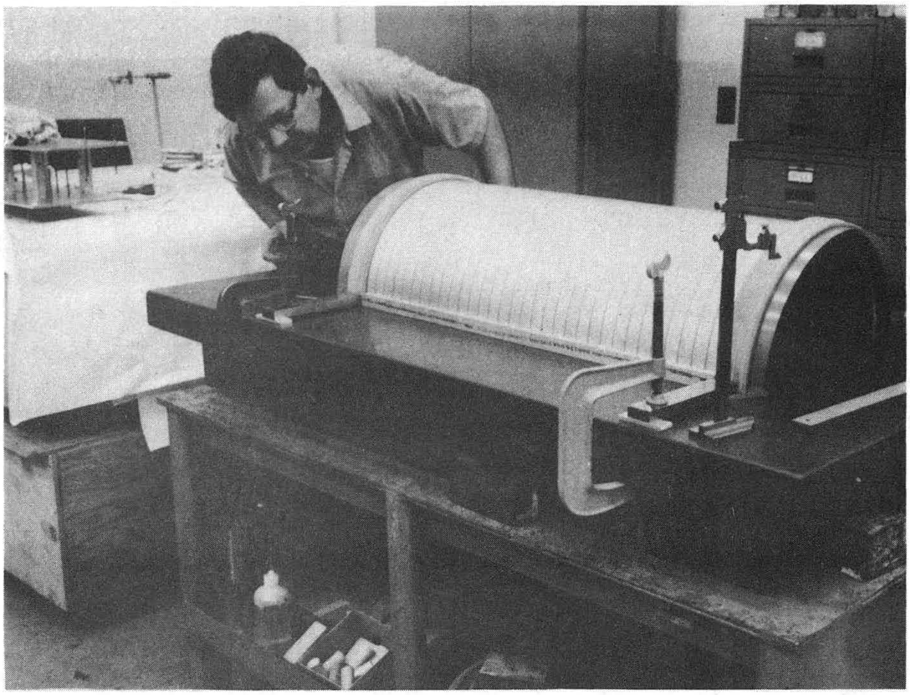

Fig. 5. Gluing of end rings on one shell.

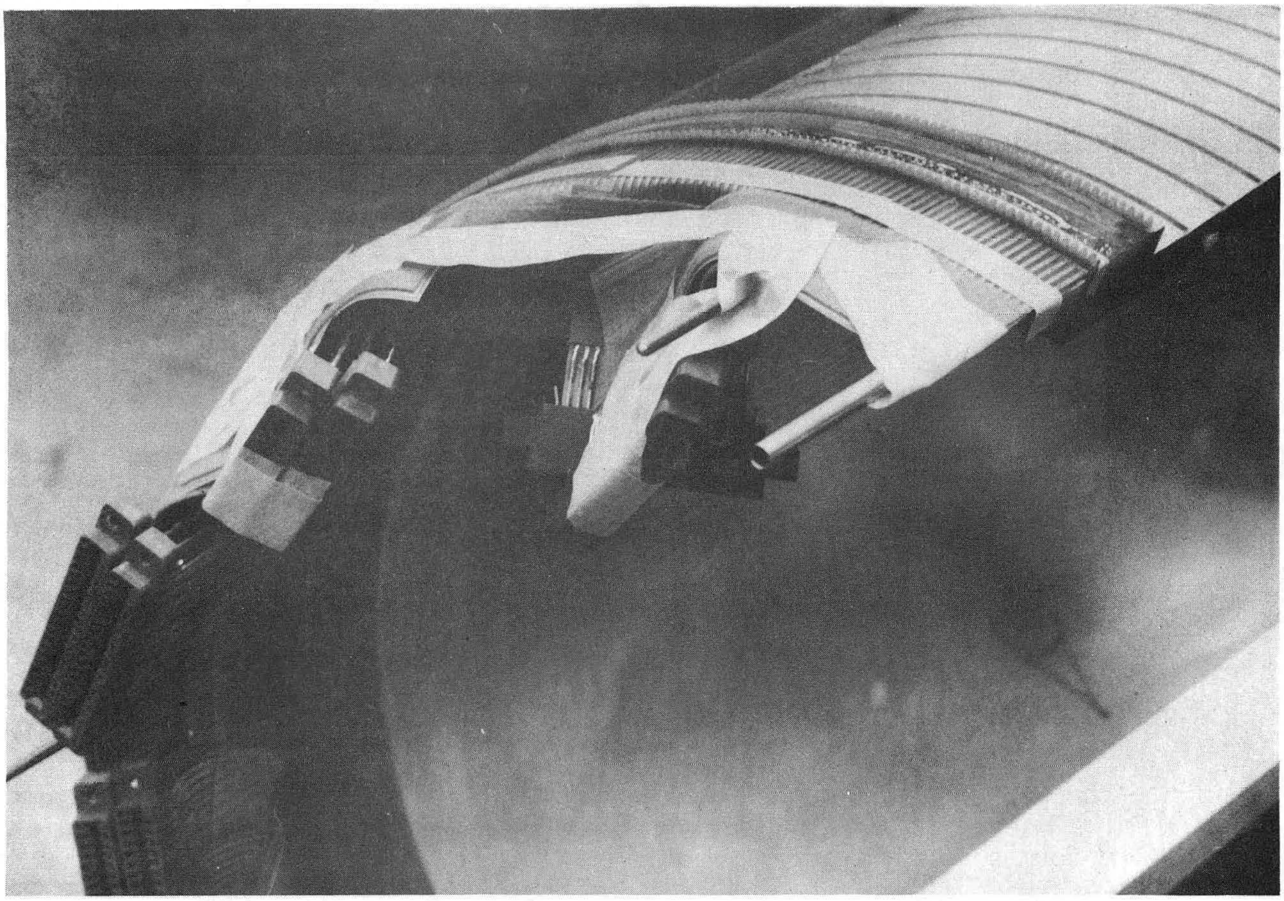

Fig. 6. Wiring operation.

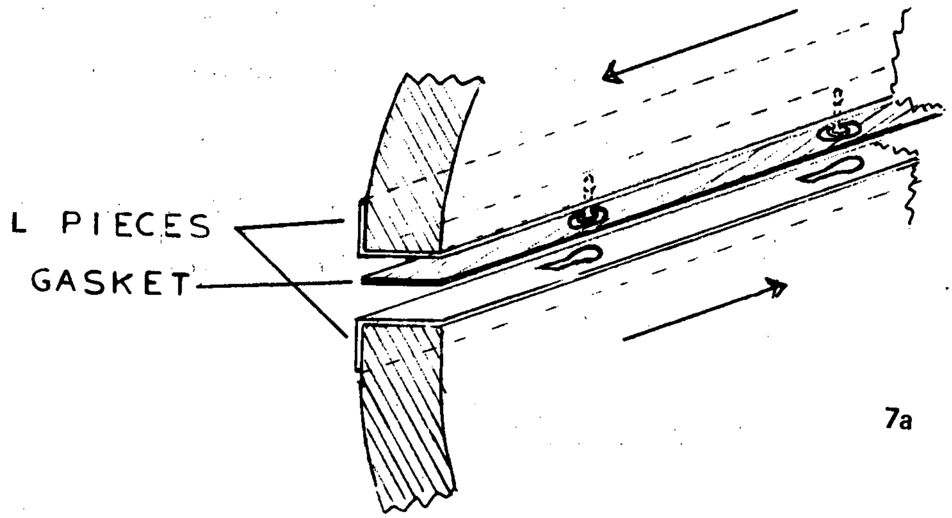

Fig. 7. a) Latching system.

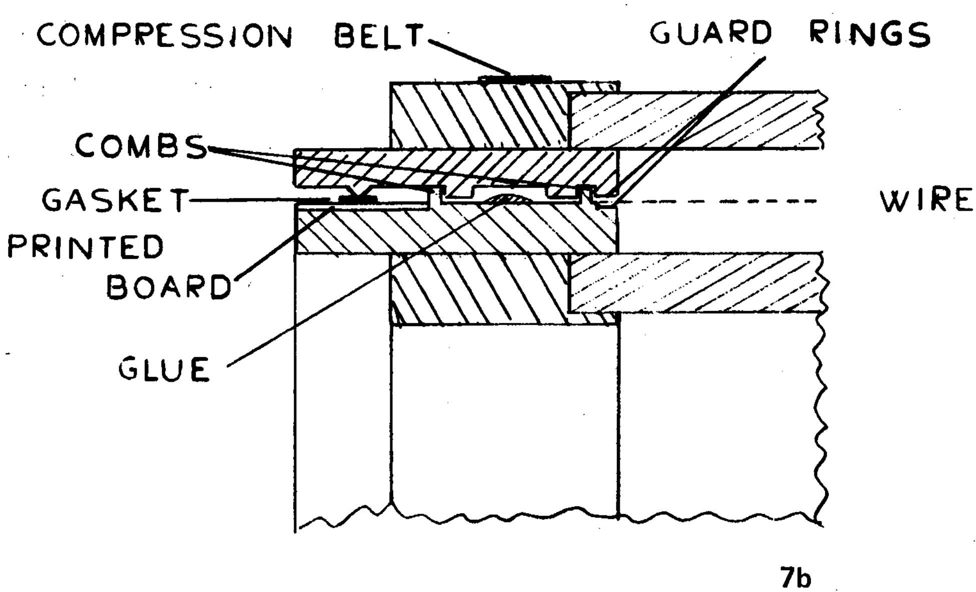

Fig. 7. b) Sealing of end rings.

We were less successful with our attempt to compress the gasket *radially* around the ends (Fig. 7b). It is difficult to apply any force that way since the end rings are very rigid. We think that sealing should be done with longitudinal compression. Care should be taken however not to change the tension of the wires. The leak rate obtained at a few mm of oil is tolerable, however (less than half a liter per hour).

2.2 Other Non-Standard Characteristics

2.2.1 Electronics

Since these chambers are located in a closed solenoid to which no access is available without one day of work, we have placed all the electronics after 10 m of Z = 82Ω-cables. Since we are loading the chamber directly by this 82Ω impedance, we have a reduction of signal amplitude. (A factor of about 5 compared to a 1 kΩ loading resistance — above 200Ω, the pulse height is *not* proportional to the loading resistance.) Simultaneously the signal width is decreased to 15ns FWHM. We had to design our own electronics since standard TTL system could not handle this kind of width. We made another mistake trying to use a single fast comparator (μA-760 Fairchild) and to have it operate at 1 mV threshold when the output has a 10ns risetime, 5 V swing. This appeared impossible, and we had to use a preamplifier.

Another interesting characteristic of our electronics is that we are able at trigger time to make a fast local coincidence between a group of 8 wires in one chamber and two groups of 8 wires in the other chamber and to count the number of such coincidences with a majority logic circuit. This proved to be extremely useful against synchroton radiation.

2.2.2 Use of a non-flammable gas

After the CERN accident last summer, we were forbidden to use a flammable gas since our chambers operate in the middle of spark chambers in a closed environment. We needed very good amplification in the gas of the kind obtained with argon-isobutane. After many attempts, guided by the work of Grunberg et al[10] in SACLAY, we found a suitable mixture: 6% of ethyl Bromide (C_2H_5Br), 18% of CO_2, balance of Argon (6% is the upper limit of non-flammability of ethyl Bromide in air). This gas has almost as good a quenching property as Argon-isobutane although its gain varies twice as fast. Local plateau curves are typically 250 V wide (around 4000 V) and limited by Geiger pulses.

2.2.3 High voltage system

We paid special attention to the reduction of the capacitance in the high voltage system, since it is well known that more than 6nf to 10 nf capacitance is dangerous for the wire in case of occasional sparking.

Our problem was that we wanted to read cathode strips, and therefore we had to have a high voltage decoupling device such as a capacitor. Because of our low impedance (cathode strips were also loaded by 82Ω), a value of 2nf per strip was necessary. Therefore the total capacitance per chamber was 128nf, much too high a value since secondary sparking between neighboring strips will connect all capacitors to the particular strip on which the primary spark occurred.

We finally used the following method: we connect cathode strips to a Z = 82Ω cable which has been carefully insulated; outside the magnetic field we decouple the high voltage with a simple (inverting 1 to 1) transformer made of three turns around a ferrite core. That way, we limit the overall capacitance to less than 5nf (including the chamber).

For safety we use a fast current sensing system actuating a trip vacuum relay. This device protects the chamber against potential sparks and beam dumps.

2.3 Operation

These two chambers have been operated continuously in the last six months. We have had no problem with wire breaking. In the last two months the rate in the chambers has been of the order of one megacycle (because of synchrotron radiation). We have seen no sign of aging so far. The dark current is smaller than 0.5 μA.

The efficiency in most of the chamber is greater than 99%. Unfortunately, along the seal between the two halves — *not* at the seal itself — we have regions of inefficiency, presumably due to a deformation of the shells which increases the gap by 1 mm in the center. The typical efficiency averaged over the chamber is 99% and 98% respectively. We will try at the next access (there have been none since we installed the chambers) to correct this effect. Global plateaus are about 250 V wide.

As often happens when an apparatus is used in an experiment, we had very little time to perform extensive tests — in particular, we never had the opportunity to optimize the cathode readout. As it stands, efficiency is 80% (we suspect a timing problem) for a threshold of about 0.8 mV. In 90% of the cases only one or two strips are hit. The resolution is compatible with what is expected from the strip width.

3. Plans

A year ago we proposed an experiment at SPEAR to measure simultaneously charged particles and photons. The idea was to shrink as much as possible the charged particle detector in order to surround it with expensive lead glass photon detector at a reasonable total cost. The solenoidal magnet (MINIMAG) was only 1 m in diameter with a field of 4 kG, and, in order to recoup a decent momentum resolution, we proposed using cylindrical high resolution drift chambers. This experiment has not been accepted by SLAC, but the Lawrence Berkeley Laboratory now plans to build a facility around PEP (a 2×15 GeV e^+e^- storage ring) with the same principle (although the radius and the field of the magnet may be somewhat higher).

To test the feasibility of such a drift chamber we are building a large scale prototype with a diameter of 90 cm and a length of 154 cm. There will be two gaps with a total of 160 sense wires and 128 cathode strips. It should be completed in October, 1975.

3.1 Method of Construction

We are using techniques very similar to those developed for the cylindrical proportional chambers. We are using Walenta's scheme of drift chamber without electric field shaping (in contrast with the method of Chaminade et al/11/ and Charpak et al/12/). The sense wire spacing is 1.7 cm (high particle multiplicity limited us to such a number) and the gap width is 2×6 mm. The two gaps of this chamber have their sense wires displaced by half a pitch in order to solve the left/right ambiguity.

We tried to develop printed delay lines in order to read the longitudinal coordinate. The best we could make with good rise-time was a 1 ns/cm line (with 20 ns rise-time and 30% attenuation after 1.5 m)(Fig. 8). A 3 ns/cm line using Atac's technique/13/ gave a rise-time of 60 ns after 1.5 m. We have finally decided to go back to the standard cathode strip technique since it is simpler to implement and gives better resolution.

Combination of the stereo between the two gaps and the *measurement of the time of the avalanche on the strip* (± 10 ns) will allow us to associate unequivocally the ϕ and z coordinate even with a large number of particles in the chamber (10 or more).

We hope to be in the region of 0.4% of X° for the mass of the total chamber.

3.2 Will It be a High Resolution Drift Chamber?

In order to get in the region of ± 100μ, all individual errors should be much smaller.

a) Intrinsic accuracy of chambers. A.Litke and I/5/ have shown that locally ± 75μ may be achieved.
   Walenta/6/ has results in the region of ± 100μ for his cylindrical chambers.

b) Electronics. Fred Kirsten and his team at LBL are building us an electronic time digitizer with $\sigma = \pm 1$ ns corresponding to ± 50μ.

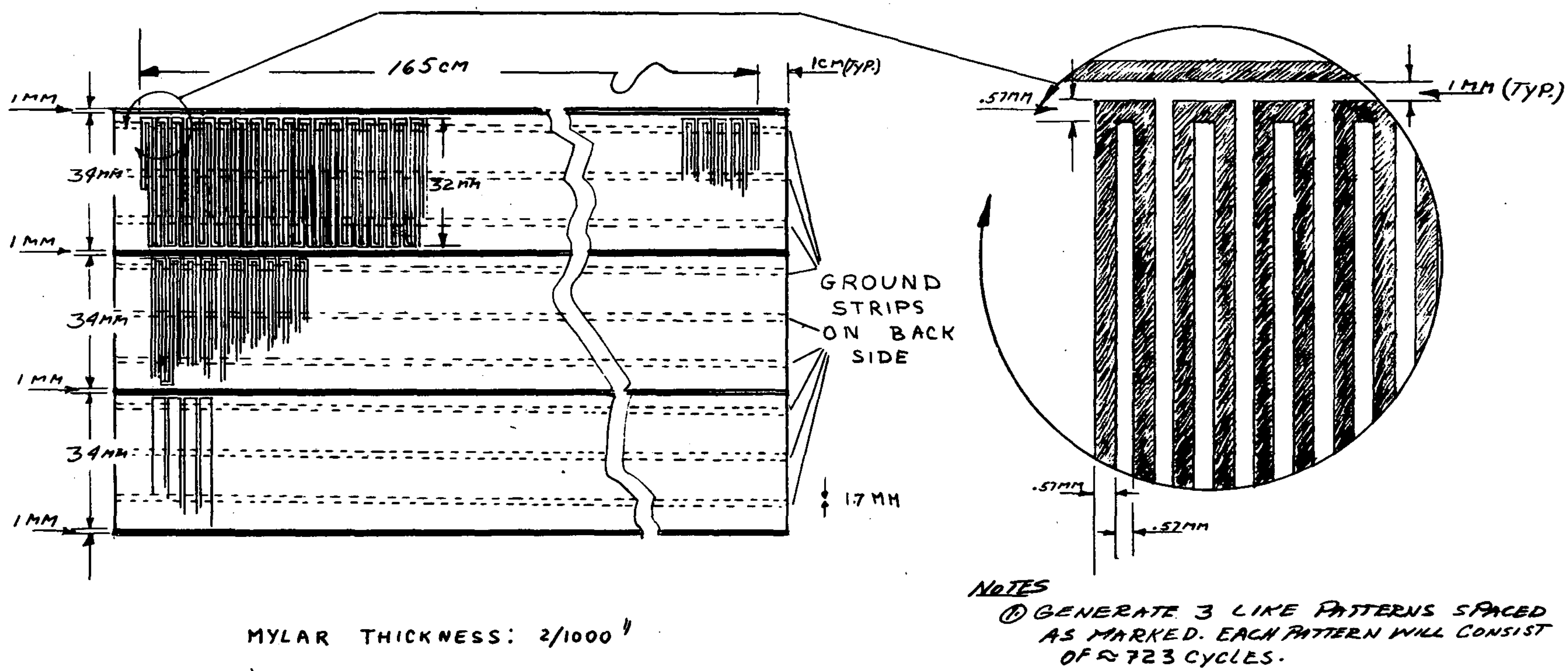

Fig. 8. Printed delay line.

c) Mechanical positioning of the wire. We are using the same system of "combs" in our proportional chamber. Their angular positioning has been specified to be accurate within ± 10 seconds of arc, their bottom on the same radius within 50μ (both tolerances not accumulative).

The end rings are prevented from rotating with respect to each other by being pinned down to two pieces of jig plate which are themselves fixed to a cylinder of a few millimeters of aluminum surrounding the chamber. The idea is that for a system of many chambers the pins will also prevent the chambers from moving with respect to each other.

d) Electrostatic stability of the wires. This is still an open question but the configuration should be stable since it is nearly cylindrical.

e) Gas stability. We hope to operate in a region of saturated drift velocity. In our previous test with 2 × 4 mm gap chambers, we still had some remaining nonuniformity of drift velocity, 2 mm around the sense wire. We are performing tests with 2 × 6 mm gap chambers where the electric field in the gap should be larger.

We hope to present results at the end of this year.

Acknowledgments

The work described on the SPEAR proportional chambers has been performed in collaboration with Alan Litke. All work was done under the auspices of the U.S. Energy Research and Development Administration.

I would like to thank N. Andersen and R. Smits for their technical help in these projects. Most of the methods described in this paper are their own.

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