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LIFETIME TESTS FOR MAC VERTEX CHAMBER*

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MAC Experiment

A vertex chamber for MAC was proposed in fall 1983 to increase precision in the measurement of the B hadron and τ lepton lifetimes. The chamber had to be placed within the existing central drift chamber, making access for repairs difficult and costly. We therefore used for detector elements thin–walled aluminized mylar drift tubes ("straws") because of their simplicity and robustness.[1,2] The diameter of the drift tubes was 6.9 mm.

The radial extent of the proposed chamber was from 4.6 cm to 10 cm, the inner wall of the central drift. It was clear that radiation levels, from synchrotron x-rays and overfocussed electrons, were potentially high. Since the drift distance is short in the straws, we wished to operate them at the highest possible gas gain, to achieve the best spatial resolution. There was a likelihood of drawing large currents in the chamber and thus causing radiation damage. We therefore undertook a study of radiation hardness under the conditions of our proposed design.

Tests were conducted in the vessel illustrated in Fig. 1. One face of the cubical vessel had a Lucite window, through which we could illuminate the straws within. A list of materials in the chamber appears in Table I. To correspond to final operating conditions, tests were conducted at 4 atma without gas circulation. Table II contains a list of gases used and operating conditions.

We have observed that pulses from the 5.9 keV x–rays from Fe^{55} remain relatively saturated for pressurized, highly quenched Argon-Hydrocarbon mixtures. However, the pulses from single primary electrons, generated by the photoelectric

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effect on the thin aluminum cathode, undergo a characteristic "jump" into the streamer mode with pulses heights comparable to those observed for Fe^{55} (Fig. 2). Presumably the large (from $\sim$ 240 primary electrons) avalanche from Fe^{55} occupies or screens the spatial region of streamer growth. The high voltages in Table II correspond, whenever possible, to this "single electron streamer" mode.

Argon-Hydrocarbons typically had a plateau of 300-500 volts for the single electron streamer mode. The large pulses associated with drift chamber operation in this mode should provide optimal spatial resolution and require modest electronics.

It was expected that predominantly Argon-CO_2 mixtures would give good lifetimes. However for such mixes there was no clear single electron streamer plateau; the mixtures are underquenched. Addition of Xenon provides a well quenched gas, without organic additives. This gas mix, 6 in Table II had a plateau of 900 volts.

The ^{55}Fe proportional pulse height spectrum was monitored at intervals throughout the lifetimes studies. In the first three Argon-Hydrocarbon mixtures, a broad continuum developed under the direct 5.9 keV and escape 3.2 keV peaks. This degradation was associated with buildup of deposits on the anode wire. At $\sim$0.05 C/cm, there was an abrupt transition to a continuous discharge. Replacing the anode wire restored operation. We concluded therefore that a discharge point had built up on the anode wire. We could not test the addition of alcohol as this dissolved the glue used to bond the drift tubes' mylar walls.

For mixtures 4-6 in Table II, the predominately Argon-CO_2 mixtures, no broad continuum appeared under the characteristic ^{55}Fe spectrum. In fact, the 5.9 keV peak narrowed as charge collected, compared with a control straw in the same gas volume. It is likely that the anode wire became cleaner. At 0.15 C/cm, the width of the 5.9 keV peak became rate dependent; by 0.25 C/cm, the pulse height spectrum was permanently broad, even for low rates. Inspection of the inside aluminized mylar wall revealed that aluminum near the source had disappeared; a transition region of greyish aluminum bordered this neighborhood; the normal shiny aluminum surrounded this. We speculate that the positive ions attack the aluminum layer when they neutralize at the cathode. It is to be noted that the cathode in our straws was a thin (.6-.8 ohm/sq surface resistivity) evaporated layer that could be relatively easily removed. CH_4 and Xe have lower ionization potentials than CO_2, so they should cause less damage when they neutralize. However, addition of these molecules did not clearly decrease the rate of cathode removal. By using a thicker aluminum layer, or perhaps by using a metal other than aluminum, one might achieve longer working lifetimes for gas mixtures limited by the cathode damage.

An end view of the MAC vertex chamber is shown in Fig. 3, a side view with shielding configuration in Fig. 4. Gas mixture 4, 49.5% Argon – 49.5% CO_2 – 1% CH_4 was chosen for use in the vertex detector. Operation began in November 1984. The operating pressure is 4 atma; the high voltage on the anode wire +3900 volts, giving 6.5 pC collected for the 5.9 keV x-ray, 3 pC in the first 10 ns.

After injection of beams 4-6 nA/cm are drawn in the inner two layers; current drawn in the outermost pair is almost a factor of 3 less. Typically two random hits per beam crossing are recorded in the chamber, and is due to synchrotron radiation from the beam halo photoconverting in the gas. This background and not the "signal" event tracks were the main source of the current drawn by the chamber.

The charge collected by the vertex detector to January 16, 1986, is given in Table III. No aging phenomena has been observed. Indeed, we are far from the regime of damage for Argon-CO_2 type gases.

CONCLUSIONS

In our tests, Argon-Hydrocarbon mixtures consistently became unusable at $\sim$ 0.05 C/cm collected charge, due to anode buildup. Argon-CO_2 mixtures, while underquenched, were operational to 0.25 C/cm, at which point loss of cathode material became intolerable. Argon-Xenon-CO_2 proved to be quenched as well as Argon-Hydrocarbons, but was limited by cathode damage. The MAC vertex chamber has operated at a distance of 4.6 cm from the e^+e^- interaction point at PEP for two years and has shown no aging effects.

REFERENCES

1. D. Rust, SLAC-PUB-3311, April 1984.
2. E. Fernandez, et al., SLAC-PUB-3390, August 1984.

TABLE I

1. Aluminized mylar straw, 6.9 mm diameter, 100 μm wall, 0.6-0.8 ohms/sq. surface resisitivity. 10 cm long.
2. Virgin Delrin 500 HV insulators.
3. Gold Tungsten anode wire, 30 μm diameter.
4. Teflon insulated coaxial cable and wire.
5. High voltage ceramic capacitors and 5% resistors.
6. Epoxy.
7. Butyl O-rings and vacuum grease.
8. Lucite window.
9. Polyflow tubing.
10. Aluminum.

TABLE II

Gases and Operating Conditions

Number	Mixture	Initial Impurities (ppm)	High Voltage (kV)	Gas Gain (^{55}Fe)	Current Drawn (μA)
1	50% Argon 50% Ethane	< 20	4.5	$2x10^6$	0.8
2	70% Argon 30% Isobutane	< 100	4.5	$2x10^6$	0.5
3	49.5% Argon 49.5% Ethane 1.0% H_2	< 20	4.6	$3x10^6$	1.3
4	50% Argon 50% CO_2	< 100	4.2	$2x10^6$	0.7
5	49.5% Argon 49.5% CO_2 1.0% CH_4	< 100	4.2	$3x10^6$	1.5
6	50% CO_2 40% Argon 10% Xenon	< 100	4.6	$3x10^6$	1.3

TABLE III

Layer	Radius (cm)	Dose (C/cm)
1	4.58	0.025
2	5.20	0.017
3	6.18	0.014
4	6.81	0.010
5	7.79	0.0093
6	8.41	0.0081

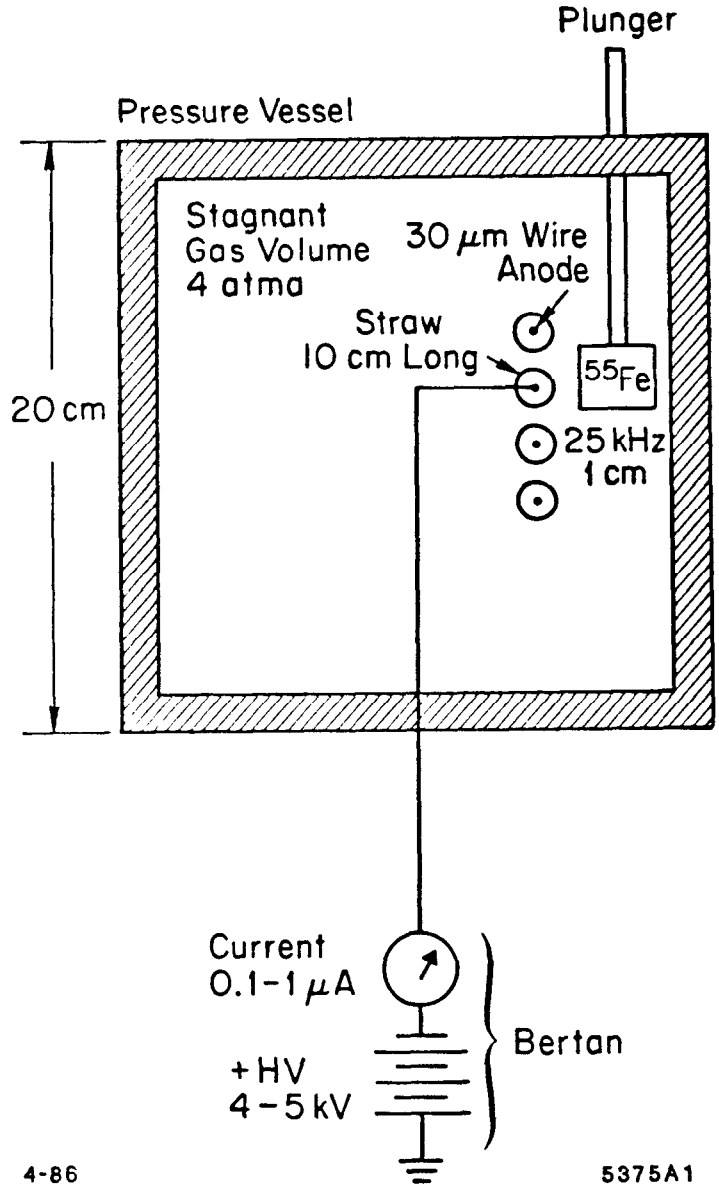

FIG. 1. Test vessel used for lifetime tests. One face of the cubical vessel had a lucite window, through which light could be shined to eject electrons from the straw cathodes via the photo-electric effect.

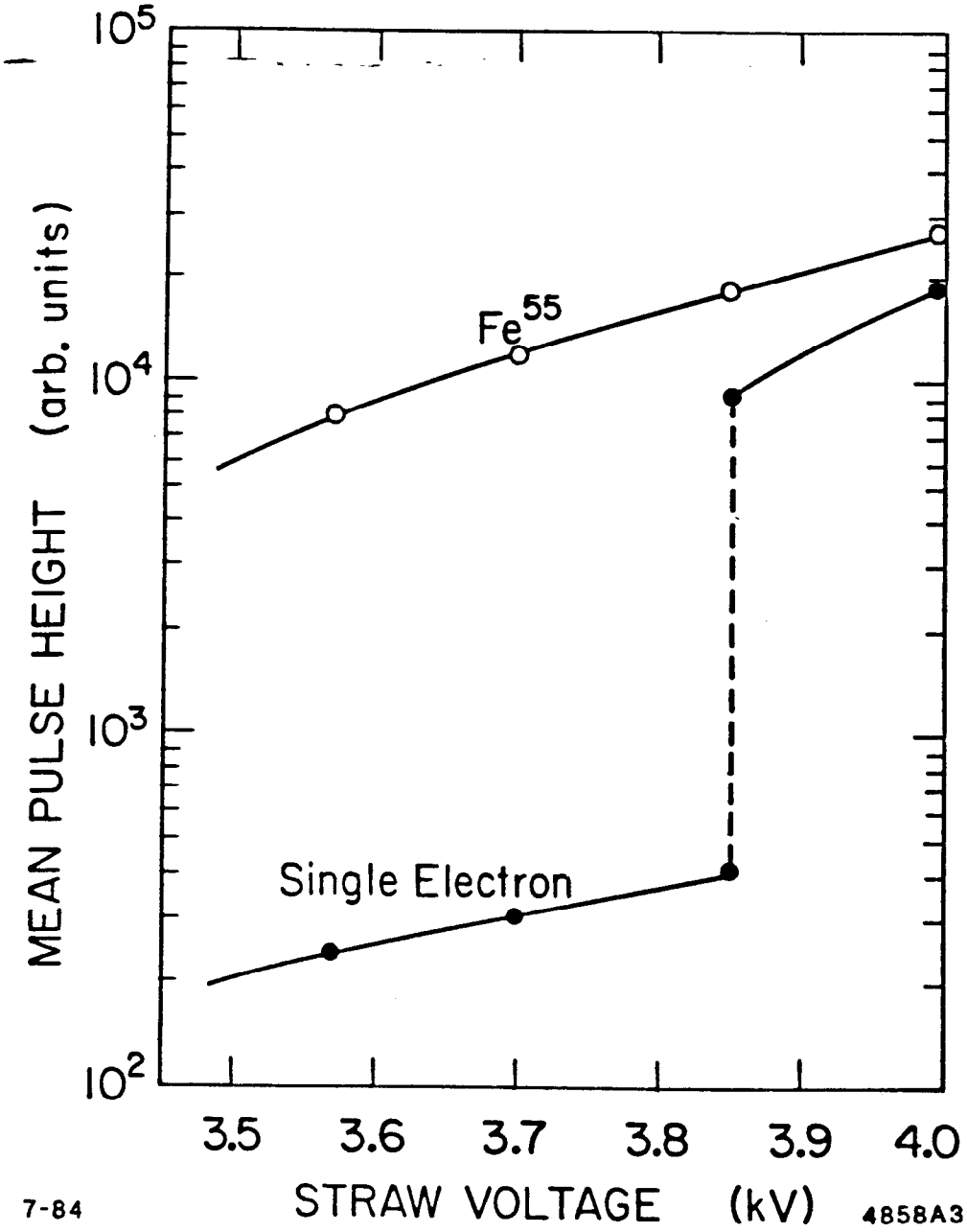

FIG. 2. Mean pulse height as function of voltage in Argon-Ethane at 4 atm.

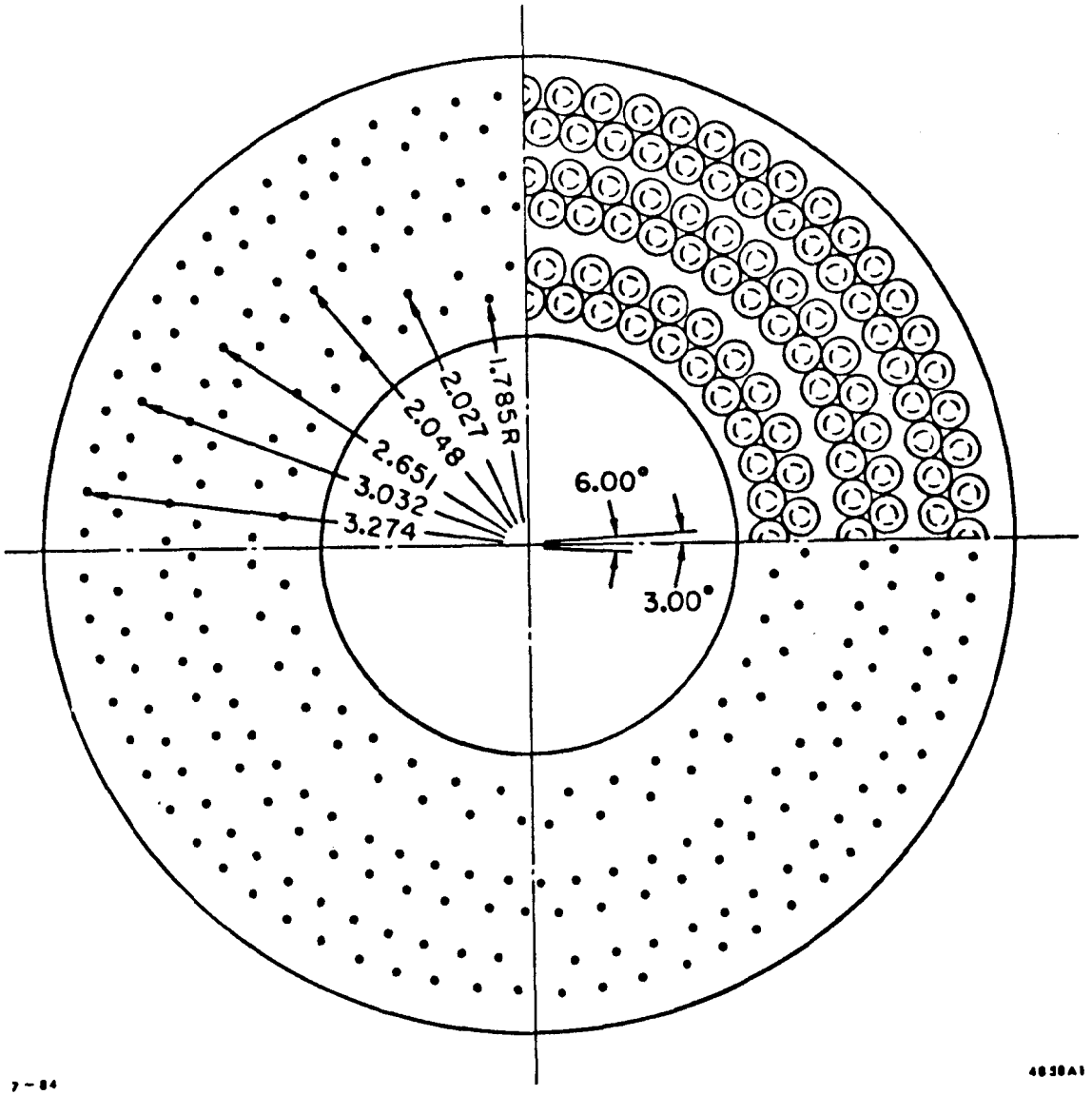

FIG. 3. Layout of the vertex chamber end-plate showing the arrangement of the 6 layers of tubes.

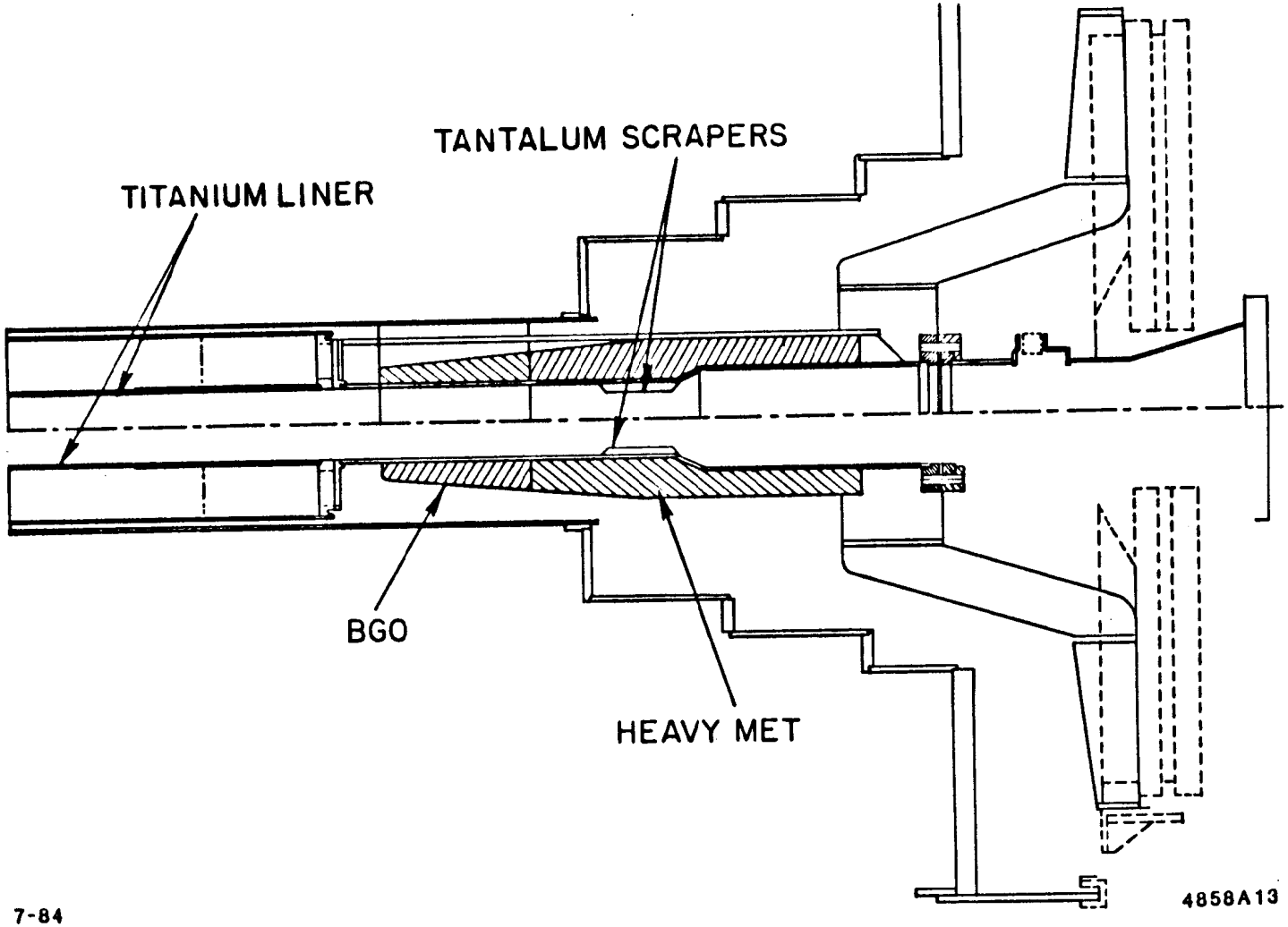

FIG. 4. Cross section of the MAC Vertex Chamber, shielding and beam pipe assembly, showing the tantalum scrapers, heavy-met absorbers, and titanium liner.