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Proposal for a beam profile monitor for the Booster ring (with application the the upgraded AGS)

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May 1988

Collider Accelerator Department

Brookhaven National Laboratory

U.S. Department of Energy

USDOE Office of Science (SC)

DISCLAIMER

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(WITH APPLICATION TO THE UPGRADED AGS)

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ACCELERATOR DEVELOPMENT DEPARTMENT

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BACKGROUND

Profile monitors measure the projection of the transverse density distribution of the beam. This allows observation of distribution assymmetry and position directly while the width provides a measurement of beam emittance. This is necessary to study matching and growth, and to document beam conditions.

There are a number of possibilities for the new profile monitor. None of these are suitable in their present form, so R and D will be required. Each technique has advantages and disadvantages which will be discussed later.

PROFILE MONITOR REQUIREMENTS

Because of the extreme high vacuum and wide beam parameter range, the Profile Monitor design will be difficult. The design requirements and considerations are summarized for the Booster case in Table I.

DISCUSSION OF SPECIFIC PROFILE MONITORS

THE PRESENT IPM

The IPM[1,2] (Figure 1) was designed by H. Weisberg and installed in the AGS in 1982. Ions generated by interaction of the beam with residual gas molecules are swept onto collecting strips by a 40 kV potential. The 64 channels per plane have a width of 1 mm on a pitch of 1.25 mm and a length of 20 cm. Each channel is connected to a gated integrator which is sequentially read into an ADC through a multiplexer. To observe polarized beams, local background gas pressure must be raised from 10^{-7} to nearly 10^{-5} Torr and the integration window increased to 10 msec.

The IPM has proved to be very useful in the AGS but with the vacuum upgrade and increased heavy ion operation its sensitivity will decrease and the controlled leak will no longer be tolerated. The construction techniques used for the IPM are not compatible with the improved vacuum and a new mechanical design would be required for the AGS.

The IPM may also show some distortion of the profiles when the beam space charge fields become comparable to the applied field. Weisberg estimated a 2.6 % increase in the sigma for a typical beam at 10^{13} ppp. It is unlikely that hardware changes will imporove this but software compensations might be applied.

AN ENHANCED IPM

The basic technique of the IPM seems well suited to the Booster and AGS. The resolution and range parameters are compatible, the technique is familiar and much of the application software can be recovered. The problem is insufficient signal for a polarized proton beam in the high vacuum. Two methods of increasing the signal are possible:

1 - Increase the number of interactions
2 - Increase the yield/interaction

THE METAL VAPOR CURTAIN

A local controlled leak can increase the number of target atoms, but makes life hard for the vacuum pumps and causes loss of heavy ions (there is a 2 % specification on beam loss). Metal vapor ribbons [3,4] (Cs, Mg, Na) have been used to enhance profile monitor signals in low intensity, high vacuum machines. They limit the high pressure region and have efficient removal using a cold trap, but are complex devices which require periodic service, have questionable reliability and are expensive. The possibility of oven runaway and potential danger to the vacuum system makes it difficult to find supporters for this technique. The device in Reference 3 was used in the SPS but not installed in the ISR. Reference 4 describes an operating device which was subsequently modified to work without the magnesium curtain[5]. There are no metal vapor curtains known to be operating in an accelerator at this time.

The equivalent pressure rise due to the metal vapor can be estimated as follows. For polarized protons, the IPM presently requires a vacuum of 10^{-5} Torr. The metal vapor curtain must give the same local pressure. This is $3x10^{5}$ times higher than the Booster vacuum, but the length is only 0.1 % of the circumference, so the average pressure would effectively be raised by a factor of 300! Even though this is not a burden on the pumps, since the metal vapor is fully collected on a cold trap, it is not acceptable for heavy ion operation. Possibly the metal vapor density could be reduced significantly during heavy ion operation, but this may not be sufficient for all species.

MICRO-CHANNEL PLATES

The second possibility is to increase the signal per ionization event. Micro-channel plates[6] (MCPs), which are imaging electron multipliers, can provide electronic gain of 6 orders of magnitude. This would make the IPM practical in the Booster vacuum and intensity range.

The MCP would preceed the collecting strips. About half of the surface area would be active channels. An incoming ion or electron would enter a channel and generate secondary electrons. An electric field across the MCP accelerates the secondary electrons down the channel where they again hit the walls and form increasing cascades. Gains of 10^3 to 10^4 for a single plate are normal, with two layers yielding gains of 10^6 to ^{7}. The Booster will require a 2-layer MCP while the AGS upgraded unit may only require one plate.

Micro-channel plates also have limitations. Poor vacuum with voltage applied can burn them out. We can easily interlock against this. MCPs are sensitive to all kinds of radiation. Finally, there is an observed secondary emission deterioration effect in which the sensitivity drops to roughly 1/2 after 0.1 Coulombs have been taken from the channel. The gain would have to be controlled to extend this lifetime limitation.

RESISTIVE PLATE PICK-UP

Another profile monitor which works on background gas interaction, uses a resistive plate pick-up[5] in place of the multi-collector array of the IPM. An MCP is used to enhance the signal from single events on this device located in the FNAL Cooling Ring (Fig. 2). It was found to be was able to operate at a vacuum of 10^{-9} Torr for beams of 2×10^6. Charge bursts from the single event hitting the resistive plate are readout thru amplifiers in the corners of the device, allowing the position to be calculated. The 4 signals are amplified, integrated, digitized and stored for 512 "events" to make a single profile. For the quoted conditions this took 200 msecs.

For the Booster parameters (3×10^{-11} Torr, 1×10^{10}, polarized protons) this would take about 4 msec at injection, increasing to 5 msec later in the cycle. Although no number was quoted, resolution of this device, from the profiles shown, appears to be about 1 mm. Because of the small number of events the profiles show a scatter. The same problem will exist for the IPM under these conditions. The number of events can be raised to improve the statistics by increasing the data sample. A problem exists for high intensity beams. At 1.5×10^{13} we would expect to acquire the same number of events in less than 1 usec. The risetime of a single event is limited by the resistivity and capacitance of the plate and is quoted at 1 usec. This implies that events occuring closer than this would run together and not be counted individually. The centroid measurement would probably be valid but profile information would be lost. It is also possible that the electronics would need to be located nearby to keep the capacitance low or further reduce the response time. This would require that they be mounted in the Booster or AGS tunnel.

THE FAST SCANNING WIRE

Another means of increasing the interaction rate is to rapidly move a thin wire through the beam. Measurement of the secondary emission current or downstream radiation on a scintillator-photomultiplier would give the density distribution. This has been done at CERN in the PS[7] and SPS[8] and at FNAL[9]. The PS device is the most applicable. Using a computer controlled drive mechanism the wire is moved through the beam in a precisely controlled path. A high velocity (20 M/s) is required to minimize the effect on the beam and heating of the wire. The calculations[8] indicate an emittance growth of 0.1 - 0.2 % at 3.5 GeV/c for protons on a 50 uM Be wire. They calculate the wire temperature rise to be 650 deg C for 10^{13} protons. Beams from 10^{9} to 10^{13} have been measured looking at secondaries with a scintillator-photomultiplier.

This device has been at CERN for several years but some problems still exist. Because of the high speed, mechanical breakage of the wire (not thermal burnout) occurs an average of once per 100 runs. This is not true of the scanners at the SPS and FNAL, which move at about 6 M/sec.

Using Booster parameters and a Linac injection emittance of 0.5-pi cm-mrad, the blow up is 24% at 200 MeV and about 3.4% at full Booster energy. Wire heating calculated for 200 MeV and $1.5\text{x}10^{13}$ protons per pulse indicates 618 deg C. However this is an average value and the peak may well be twice this temperature. Even allowing for momentum compaction, the melting point of tungsten will not be reached. This is an over estimate since radiation cooling has not been taken into account. If the scan is slowed from 20 M/sec to 6 M/sec, as at the SPS and FNAL, to eliminate wire breakage, the temperature rise approaches the melting point. In the case of heavy ions, interaction with the wire will cause the beam to be lost.

CHOICE OF A DETECTOR

The various profile monitors described each have advantages and disadvantages, which are summarized in Table II. No detector exists which is tested and totally suitable for the Booster. There are serious drawbacks which cause all but the IPM with MCPs to be rejected at this time. Even the IPM will require further study of several problem areas before there can be confidence in its success.

The use of a metal vapor curtain to enhance the background gas will produce sufficient signals over the entire intensity range. For polarized protons beam loss from interaction with the vapor is not a problem, but it may be for some of the heavy ions. A more serious drawback is the real possibility of contaminating the vacuum chamber either through a malfunction or long-term low level deposition. Such a low work-function coating would require dissassembly and cleaning of the vacuum chambers and represents an unacceptable risk.

The Resistive Plate Pick-up requires 4 electronics channels (2 will work also) compared to 64 for the IPM, although the electronics are more sophisticated. The signal statistics are the same as for the IPM: there are few ions at this vacuum for low intensity beams. The problem comes with the high intensity beams, which generate events too close in time to be resolved. At full proton intensity the data frame will be filled in a time comparable to the signal rise time, providing no spatial resolution. Thus the Resistive Plate Pick-up must be rejected.

The Fast Wire Scanner presents a number of problems which preclude its use in the Booster. At Linac injection energy the emittance blow-up is intolerable. Wire breakage is a problem with the high speed (PS) version but when the speed is reduced thermal burnout may be possible. Finally, heavy ion beams will be destroyed by the wire. These difficulties make the Fast Wire Scanner unacceptable.

The IPM enhanced by MCPs has a number of limitations also. None of these present a problem for the beam or appear to be an obviously insurmountable obstacle, however, several areas require further study.

DISCUSSION OF CONCERNS WITH THE IPM

Estimate of Signal Level

The number of ion pairs per centimeter of collector is given by Equation 1 :

$$\#/s = N * f_r * \frac{dE}{dX} * \frac{1}{Ei} * \frac{P}{760} * p$$

Where:

N = Number of circulating protons
f_r = Revolution frequency
dE/dX = Energy loss [MeV/cm]
Ei = Ionization potential [eV]
P = Pressure [Torr]
p = Density [gm/cm^3]

The energy loss per centimeter and the ionization potential are functions of the gas molecule and are taken from Reference 10. The residual gas in a high vacuum system depends on the cleaning and pumping techniques employed. For the Booster case it is believed that there will be 90 % diatomic hydrogen and 10 % carbon monoxide[11]. Since CO is not presented in the data of Reference 10, diatomic nitrogen was used in its place. The expected ion pairs produced as a function of energy is shown in Figure 3 for a vacuum of 3×10^{-11} Torr and 10^{10} polarized protons.

An 8 cm long detector would collect 126.4 ion pairs/msec at 200 MeV. For a beam of 2 cm full width, the center 1 mm collector would get 10 % of the total charge. For a 1 msec collection time the statistical variation would be 28 % due to the small number of events. In reality the number of observed events is about half this due to the 90% transparency of the ground plane mesh and 57% active area of the MCP. The MCP doesn't help the statistics: it only makes the signal fluctuations easier to observed.

This problem is only significant for the polarized protons, since the energy loss for heavy ions will go as Z^2. In practice the polarized protons injected into the AGS is already 2×10^{10} and should increase due to the shorter, improved injection line and significant improvements in the source. It is not unreasonable to invoke a factor of at least 4 and more likely 10 by the time the Booster requires beam. Moreover, polarized beam will be stacked in the Booster for 20 pulses, further improving the signal. The integration time could be extended but this will reduce the time available for data acquisition.

The center channel signal current for a 1×10^{10} proton beam would be 1.04 nA. This is a measurable signal for the 4-Channel Integrator module widely used in beam intrumentation at the AGS. Experience has shown the error currents for these to be between 1 and 10 pA. Assuming the same gain as the present IPM, this would produce a voltage of 47 mV. Considering that 20 pulses will be stacked, and that this is a low estimate of the typical intensity, this is an acceptable number. The 4-Channel Integrator can switch between 2 capacitor values to handle higher currents if required.

The Secondary Emission Deterioration Problem

Micro-Channel plates provide gain by secondary emission cascade down the channel. The secondary emission coefficient at the end of the channel has been found to deteriorate with total charge extracted. Figure 4 shows this effect for a typical MCP[12]. At about 0.1 Coulomb/cm^2 the efficiency has fallen by half. How long will an IPM operate before reaching this condition?

For a center channel signal of 4.14 nA, corresponding to a typical 4×10^{10} polarized proton beam, and a collector area of $0.1 \times 8\ cm^2$, the current density is 5.17 nA/cm^2. Since the Booster cycle is 60 msec long, the 0.1 Coulomb/cm^2 limit will be reached in 3.22×10^8 pulses, or 498 days at a rep-rate of 7.5 Hz. A 50 % loss of sensitivity would probably not be acceptable since it is not uniform across the channels. A 10 % loss would be seen after only 50 days, which is not practical.

This could be improved in several ways. First, gate the gain voltage to correspond to the integrator window. This would be for a maximum of 1 msec times 10 reads/pulse for 10 msec instead of 60 msec, extending the lifetime to 300 days. Secondly, the voltage should be applied only when a measurement is in process. Even with the absurd assumption that the IPM would be used 10 % of the time, this gives 3000 days or 15 years of running time. This is long enough that much higher signal current could be tolerated.

Thus secondary emission deterioration will not be a problem if the MCP gain voltage is on only when a measurement is being made, and only during the integrator gate time. Since the gain voltage is of the order of 1 kV per MCP, a small vacuum tube switching an adjustable HVPS would work. The power supply and current limiting resistors must be chosen to allow the short rise and fall times times. As an example, the current to charge 1000-ft of cable (30 pF/ft) to 2 kV (2 stage MCP) with a 1 usec rise time would be an impractical 60 A. This could be solved by placing the tube close to the IPM (10-ft would require 0.6 A), or by relaxing the rise time requirement to 100 us (at the same current). If a 1 ms rise time could be tolerated (the integrator does the fast gating) then only 60 mA would be required.

Provision must also be made to decrease the gain for higher intensity beams. Since the intensity will vary by more than 10^3 the gain must vary from 10^6 to less than 10^3, which can easily be done by adjusting the gain power supply. This should be done automatically by the control computer.

The Current Saturation Problem

Another potential problem is current saturation in the MCPs. The data sheets in Reference 12 indicate that the output is linear up to the 7 % of the "strip" current (the applied voltage divided by the plate resistance). The worst case would be at the lowest applied voltage (about 500 V) and a high intensity beam. For the quoted plate resistance of 20 MOhms the 7 % limit would be at 1.75 uA. Since the expected signal currents will be less than 1 % of this no non-linearity should be observed as long as the gain-limiting voltage control is used.

The Radiation Sensitivity Problem

Any ionizing radiation such as background activation or beam halo, which strikes the MCP, could cause a false signal. Fortunately they are most sensitive to ions in the 2 - 50 keV range (60 - 85 % efficient) and electrons from 2 - 50 keV (10 - 60 % efficient)[13]. X-rays in the 0.2 - 0.5 Angstrom range are 5 - 15 % efficient. Although intense background may cause signals, this would mostly be the case at high intensity when the gain would be greatly reduced anyway, lessening the problem.

Unfortunately the effect of radiation can't be clearly evaluated before hand. A test on a unit in the AGS is proposed to study this problem.

The Ion/Electron Bombardment Problem

The anode and ground electrodes of the original AGS IPM showed heating discoloration when removed from the vacuum. Electron and ion bombardment was believed to be the cause.

Turning the HV power supply off 15 minutes after the last scan has eliminated the problem. Since the MCPs may be even more sensitive to bombardment, the HV power supply should be on only for the period of a Booster or AGS cycle. Since the supply will not come to full voltage immediately, it must be monitored to tell the electronics when the scan can begin. This will result in the HV being on for perhaps several seconds before the scan begins, but considerably less than 15 minutes. Even less time would be required if a high voltage vacuum tube was used to switch the HV rather than turning the power supply on and off, but cost might preclude this option.

Divergence of the Beamlets From the MCP

The electron stream coming from the MCP may have considerable divergence depending upon where the electrons were created along the channel. The worst case would be for electrons created on the last wall collision near the end of the channel. For a typical plate of 600 uM thickness and 20 uM diameter, geometrical divergences of 300 mradian or more are possible. A post MCP accelerating field of several hundred volts would be sufficient to transport the spatial data to the pick-up collector array.

High Vacuum Considerations

The present AGS IPM was designed for a 10^{-6} to 10^{-7} Torr vacuum system. Plastic coated wire with braided shielding, plastic insulators and components with trapped air volumes are certainly not suited to the Booster vacuum. A completely new mechanical design of a unit for 10^{-11} Torr vacuum and bakable to 200-250 deg C is required. The MCPs are qualified for 350 deg C bakout. The same IPMs with a single MCP would be suitable for the Upgraded AGS.

Data Processing Considerations

Assuming 64 channels per plane, 10 reads per Booster cycle and a 1 msec integration window, about 40 usec per channel is available to digitize and put into memory. This must include overhead for operating systems, interrupt service, pointer setups, etc. In HITL a similar application required more than 100 usec. Improvments in the ADC and CPU reduced this to 50 usec in the LEBT Upgrade Instrumentation Controller, but that is still not fast enough. If more than 64 channels per plane are required (96 has been proposed) then even 40 usec is too slow and perhaps the design should be based on 20 to 25 usec.It should be noted that the 40 usec throughput does not leave any time for data transmission between scans so all 10 must be locally stored and transmitted after the cycle is done. This could be during the magnet down-ramp or the next cycle if consecutive reads are not required.

The IPM readout might best be handled with a dedicated CPU with minimal operating system, and a fast ADC, located in the same crate with the signal conditioning electronics, to meet these requirements. This would also allow the use of front-end intelligence to process the data and send only a reduced set out on the LAN to the Instrument Controller or Station.

As an example, the Plessey PME-98-06, 64 Channel Analog Input Board has 64, 12-bit inputs, 25 usec throughput time and is in VME format. It can be put in the same crate with Eurocard modules used for the signal conditioning. There are many processors which would work with this module, for example, the Plessey PME-68-14 Single Board Computer, which can support 2 MB on-board DRAM and has complete IEEE-488 capability. This could talk to an Instrument Controller or directly to a Station. Alternatively, a DATACON or OPTACON board could be put into the crate to connect to the LAN.

Other applications in the Booster (transport line HARPs) will have similar requirements for the analog signal processing electronics. A repackaging of the HITL HARP electronics is being proposed which will allow all 64 channels of gated integrator, a 64 channel scanner (analog multiplexer) and control circuits to be housed in a single 6U-high Eurocard crate (the new instrumentation standard). This will involve the design of an 8-Channel Integrator Module and a 64-Channel Scanner Module in the Eurocard format. Each plane of the IPM could be read by one of these crates, with both crates being controlled by the same processor.

THE PROPOSED NEW IPM

Figure 5 shows a schematic layout of the proposed Enhanced IPM. Two MCPs are shown with an integral multi-collector anode (MCA) which various manufacturers offer as an option. In fact some even offer the unit complete with vacuum feedthru of these connections. This should be investigated and if applicable in the Booster vacuum, should be purchased as part of the assembly. If this is not practical, a flexible Kapton printed circuit strip can bring the signals from the MCA to the vacuum headers. The layout of the Kapton PC should allow simple direct soldering to a ceramic connector which mates to the header, eliminating all of the labor intensive wiring.

The stainless steel upper electrode (anode) will be connected to a high voltage vacuum feedthru rated for voltages up to 50 kV. The opposite electrode will be at the HV PS return potential, not beam pipe ground, which will bounce with the magnet ramp and beam RF. The Bias Voltage pulls away all secondary emission electrons produced on the top MCP surface to prevent diffusion of the image. The Gain Voltage is divided to provide equal gain for the 2 MCPs and a post MCP acceleration to the MCA.

The high voltage switches for the HV PS and the MCP Gain PS are also shown. The HV PS may instead be turned on and off by switching its AC line. The Gain Voltage Switch Tube must be located within 10 feet of the IPM for fast gating.

The electronics for the new unit should follow the recommendations above. This would allow reading and storing in memory of all 64-channels of both planes within 6 msec for all 10 scans per Booster cycle. In addition control of the MCP Gain Voltage should be locally controlled to track with the total collected current and/or beam intensity, but have console control possible. The Instrument Controller must also provide timing pulses for gating the Gain Voltage and control turning the HV on and off.

FEASABILITY TEST IN THE AGS

In addition to the two IPMs installed in the AGS there are a complete spare 64-channel unit and a 96-channel unit. There is sufficient space in the pick-up box to drop the collector array and place an MCP in front of it. If the MCP was sized to cover the full width of the array (80 mm) but only a portion of its length then the IPM could operate with nearly sensitivity with the MCP off, and have increased signal by 100 to 1000 times with the MCP on.

There are, however, a few problems. The present IPM collects ions, while the MCP delivers electrons regardless of the input. This would reverse the polarity of the output signals, but the electronics can accomodate this.

For convenience in construction, the IPM was built using 2 offset rows of collectors. This difference in depth may cause the collection efficiency to be unequal for the two sets of collectors and show an alternate high-low pattern. This should be analyzed to determine if post-MCP acceleration will eliminate this effect or if a new single plane collector must be built.

The MCP will require as much as 1 kV gain voltage. A new vacuum feedthru and proper vacuum insulation must be provided. A means of adjusting and switching the gain voltage must also be added.

An MCP of 80 x 30 mm is available from Hamamatsu, "off the shelf" in Japan. Delivery is still 30 -45 days. To install this test unit by the summer shut down is crucial if we are to have a profile monitor design concept which we believe to be feasible for the Booster. Work must begin immediately to prepare for this test. The mechanical modifications must be drawn up and the gain voltage control and switching provided.

CONCLUSION

Only the IPM with Micro-Channel Plates appears to satisfy the needs of the Booster and the Upgraded AGS for profile measurements in a high vacuum Ring with low intensity beams.

Provision must be made to limit the current drawn from the MCPs to prevent saturation and long term secondary emission deterioration. This can be done by adjusting the gain according to the intensity and the beam width, and by gating the MCP bias voltage with the integration window signal, and only when a measurement is requested. In this way a lifetime of more than 10 years is expected. The gain voltage must be shut off in the event the vacuum becomes worse than 10^{-6} Torr.

The high voltage must be put on only for the duration of the measurement to prevent burning the MCPs. The high voltage must be shut off if the vacuum is worse than 10^{-6} Torr.

Post MCP acceleration will be required to retain spatial coherence.

Statistical noise will be significant for 10^{10} polarized proton beams in a vacuum of 3×10^{-11} Torr, but actual beam intensity is expected to be much higher.

The required 25 usec digitization-to-memory time exceeds the present data rate by a factor of 2. A dedicated in-crate CPU/ADC in VME format should be investigated.

The effect of background radiation on the MCPs is a potential problem. One of the existing AGS units should be adapted to use an MCP to evaluate the situation at the earliest possible time.

A draft mechanical layout of the Booster IPM system is required at an early time since the Ring vacuum system must include provision for its vacuum box. The design should be detailled enough to allow the box size and shape, and any necessary feedthrus to be determined.

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TABLE I

DESIGN PARAMETERS

PARAMETER	AGS	BOOSTER
INTENSITY (particles/pulse)		
PROTONS		
Maximum	1.5×10^{13} ppp	
POLARIZED PROTONS		
Minimum	1.0×10^{10} ppp	
LIGHT IONS		
Minimum	1.0×10^{10} ppp	
HEAVY IONS		
Minimum	1.0×10^{08} ppp	
BEAM RADIUS (Observed at Injection in AGS)		
PROTONS		
Horizontal (RMS)	12 mm	
Vertical (RMS)	10 mm	
LIGHT IONS		
Horizontal (RMS)	12 mm	
Vertical (RMS)	5 mm	
RESOLUTION		
SPATIAL (~ 1/4 sigma)	1 mm	
AMPLITUDE	12 Bits	
TIME	1 - 6 mSec	
DETECTOR RANGE(~ 2.5 sigma)	+/- 32 mm	
REFRESH RATE (#/cycle)	10	
BEAM LOSS	< 2 %	
OPERATING VACUUM	3×10^{-11} Torr	

OTHER DESIGN CONSIDERATIONS

BAKABLE TO 200 - 250 deg C
RETAIN FULL BEAM PIPE APERTURE
SIMPLE TO OPERATE
MUST BE SELF-PROTECTING
OPERATE IN RADIATION FIELD OF 10000 RAD/YR

TABLE II

DETECTOR	ADVANTAGES	DISADVANTAGES
IPM WITH MCP	-100 % non-intercepting -Compatible with present device - Can work over full intensity range	-Sensitive to all radiation -Can saturate at high intensity -Life limited by depletion
IPM WITH METAL VAPOR CURTAIN	- No electronic gain required - Can work over full intensity range	-Metal vapor source is complicated -Potential of major vacuum disaster -Pressure too high for heavy ions
RESISTIVE PLATE WITH MCP	- 100 % non-intercepting - Simpler electronics than IPM	- Same as for IPM - Signals pile-up for high intensity
FAST WIRE SCANNER	- Some existing designs	- Wire breakage - Wire burnout at high intensity - Emittance Growth - Kills heavy ions

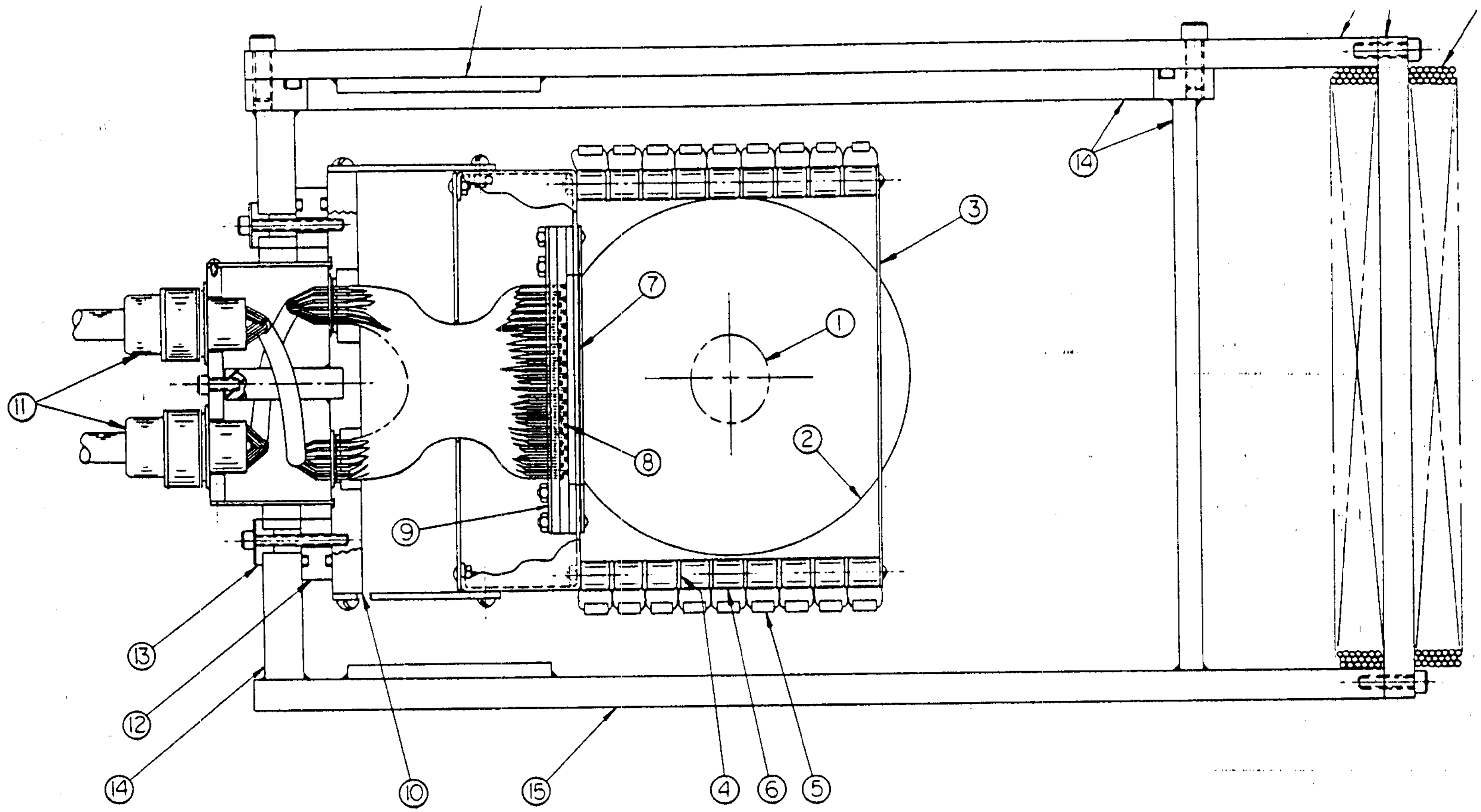

FIG 1. AGS IPM

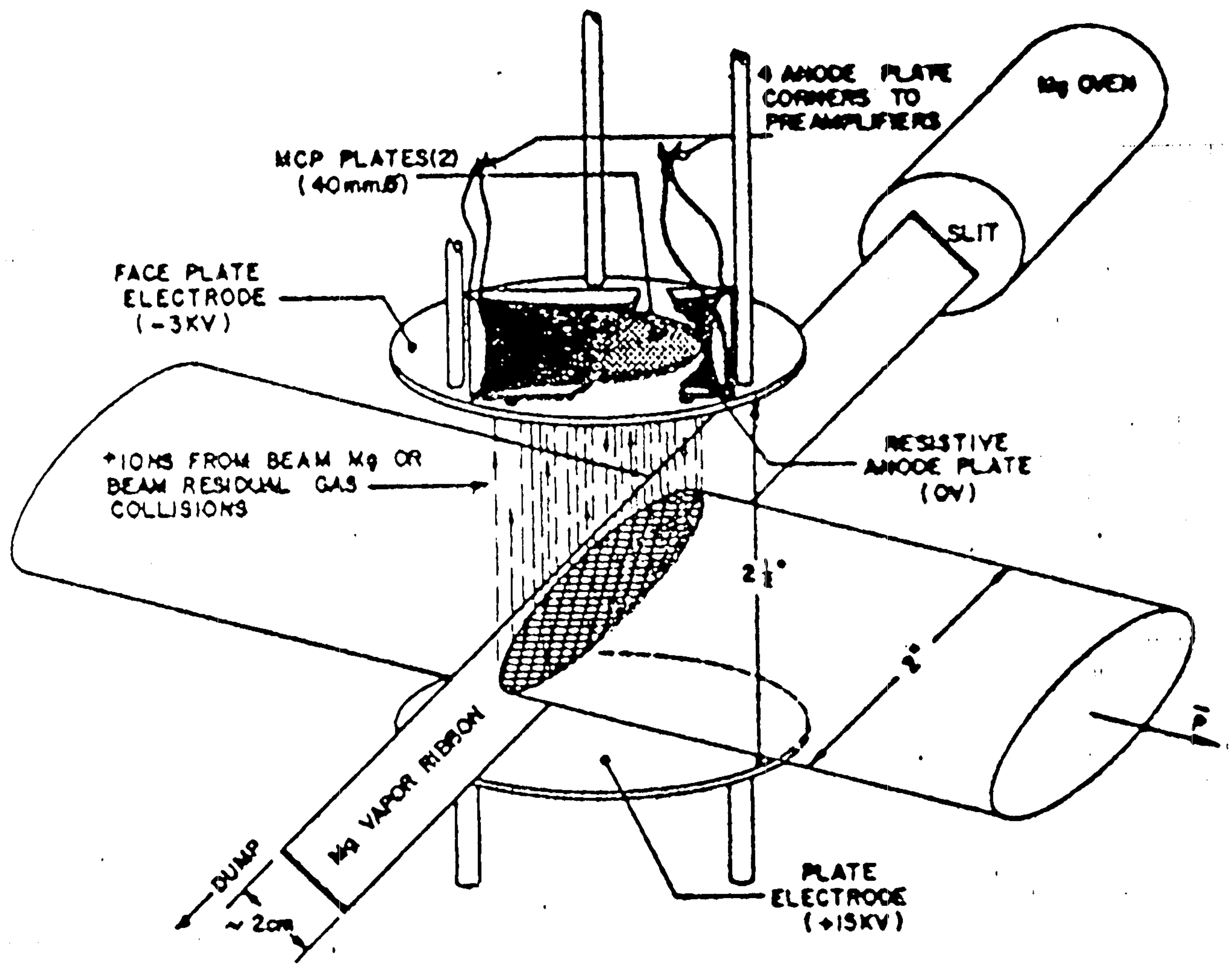

FIG 2. FNAL COOLING RING PROFILE MONITOR
(Mg BEAM NOT USED)

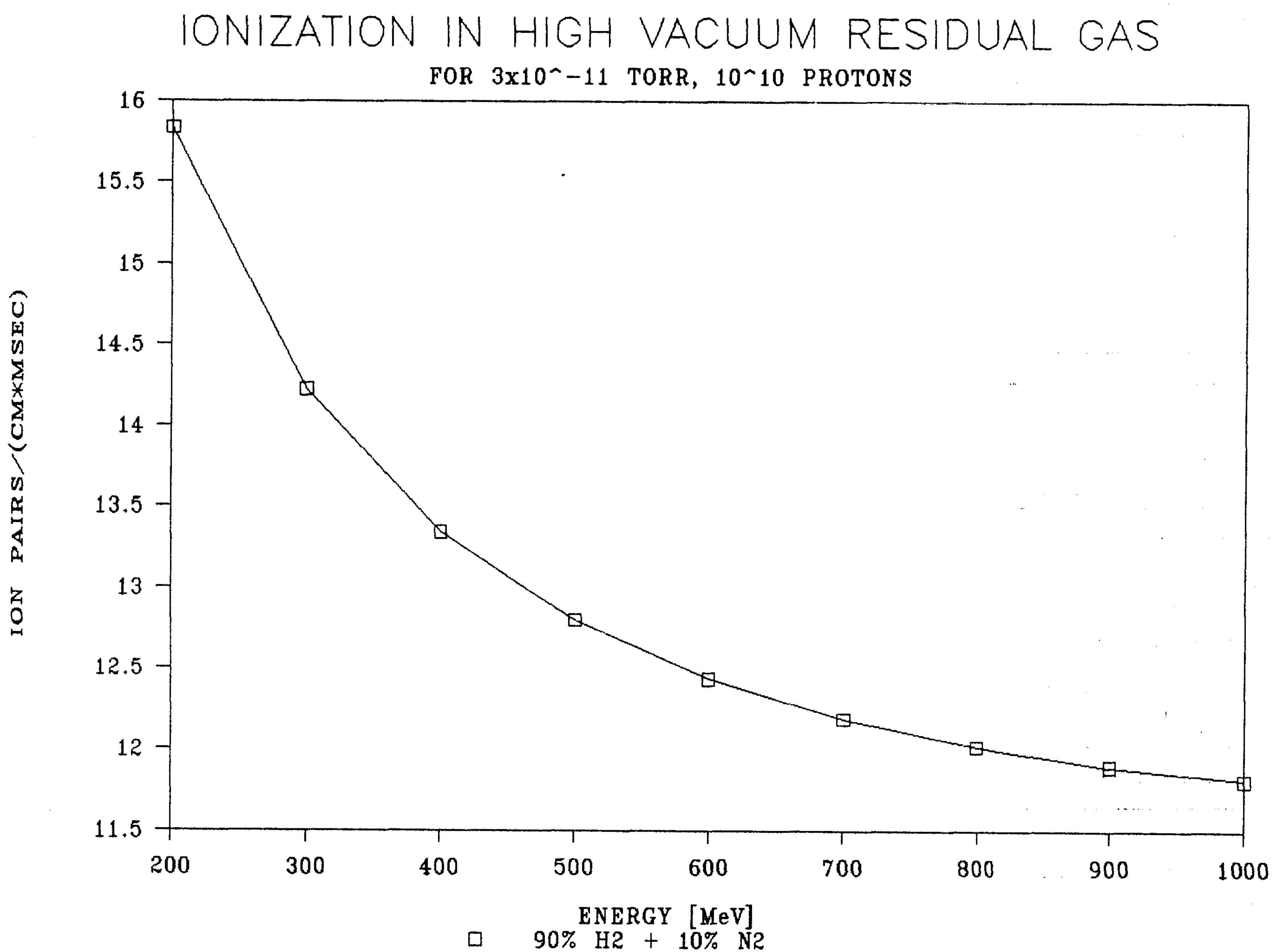

FIG. 3- EXPECTED ION PRODUCTION

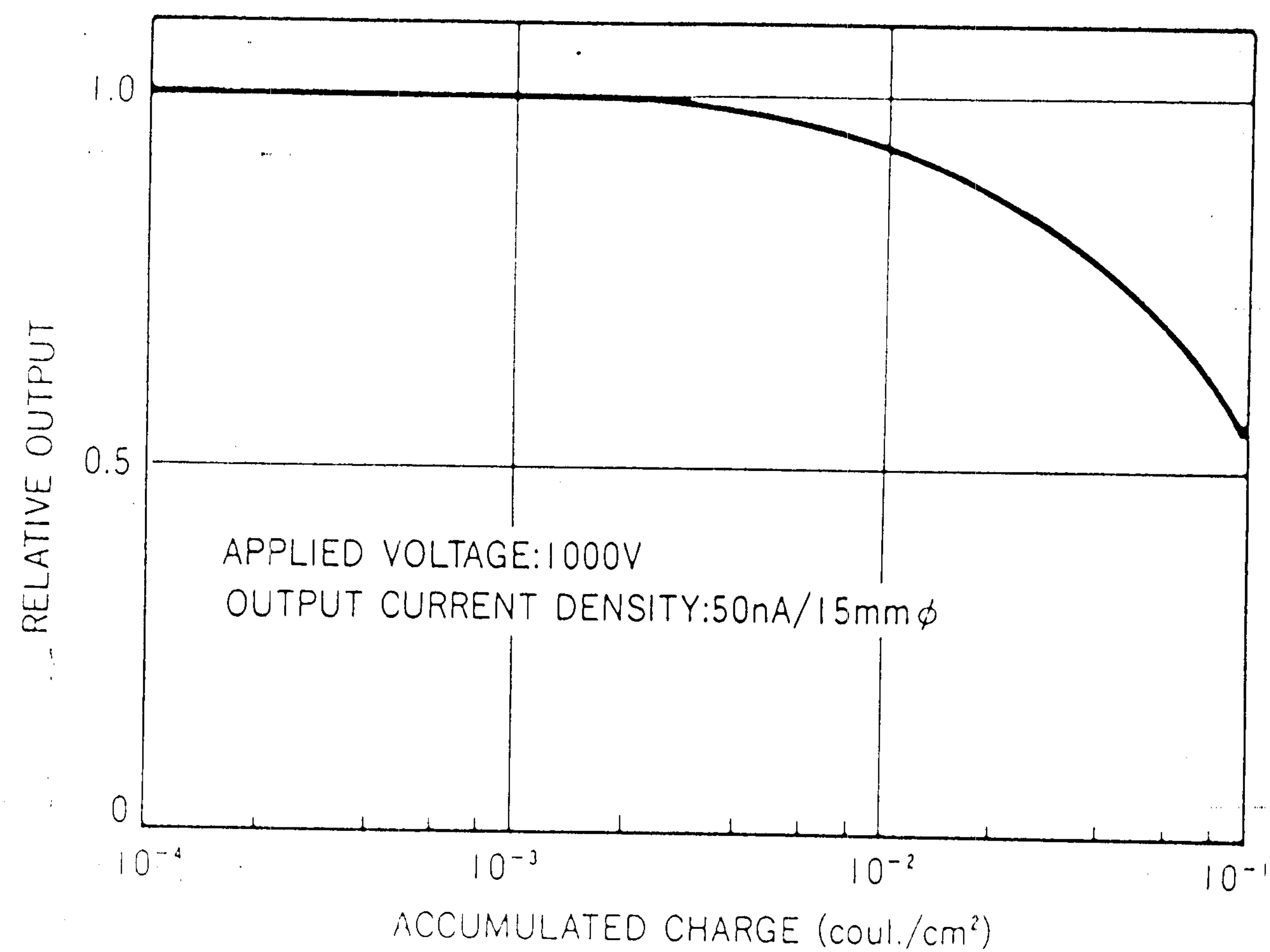

FIG 4. MCP LIFETIME

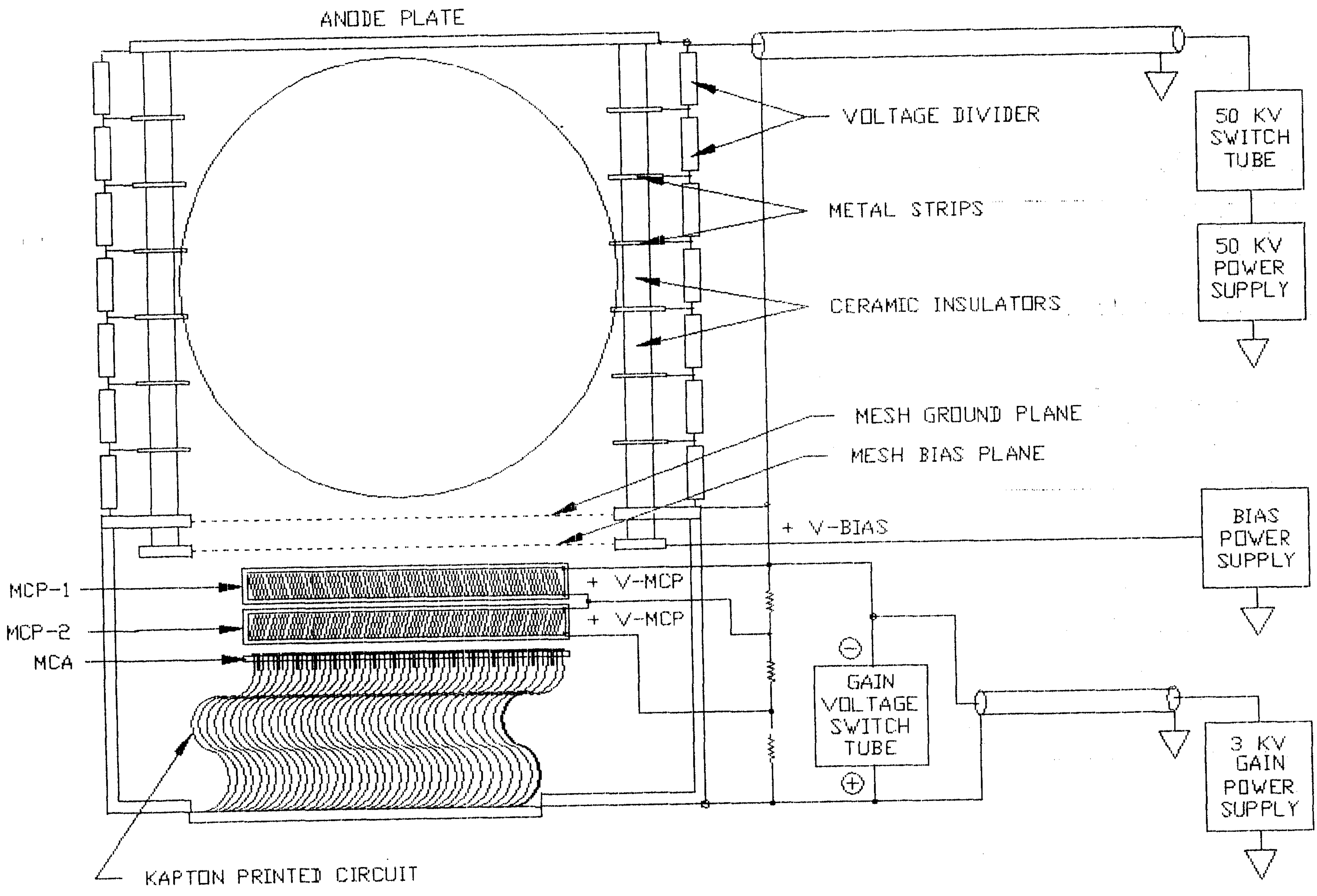

FIG 5. PROPOSED ENHANCED IPM