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THE CEA SECONDARY EMISSION MONITORS

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November 4, 1968

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
and HARVARD UNIVERSITY

CAMBRIDGE ELECTRON ACCELERATOR

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Introduction

Several secondary emission monitors (SEM) have been developed at CEA for monitoring the external electron beam. The operation and characteristics of the first units were reported earlier¹. The conclusions drawn from their performance as to usable aperture, length, and weight led to the construction of monitors of improved design (SEM 4, SEM 5, and SEM 6) that are presently in use at CEA. This report contains information, accumulated over a period of about two years, that is pertinent to the response and energy dependence of these monitors.

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Description

Each monitor consists of nine thin metal foils spaced 0.5" apart (Fig. 1). These foils are stretched over 10.5" I.D. stainless steel rings by circular springs. Since the response ($\text{SEM charge/Faraday Cup charge} = q_{\text{SEM}}/q_{\text{FC}}$) shows little dependence on variation in the electric field when the SEM is operated in the plateau-like region of the bias curve (Fig. 2), no particular effort was made to bring the combined deviation from flatness and parallelism of the foils to less than 1/16".

The ring assembly is mounted in a cylindrical stainless steel vacuum enclosure (12.5" dia., 7.5" deep) which includes two thin windows (0.003" stainless steel) welded to the main body. An 8 liter/sec titanium-discharge Vacion pump is permanently connected to the vacuum enclosure. The entire enclosure was acid-etched prior to final assembly and has been continuously maintained under vacuum throughout the two year period. Base pressures in the range 10^{-8} torr to 3×10^{-8} torr were attained in all monitors. The total thickness of each SEM is less than $0.01 X_0$.

The foils incorporated in each SEM are as follows:

SEM 4: Each foil is 0.0003" aluminum that is coated on each side by vacuum evaporation with a gold layer (about 4 microinches thick). One surface has a brighter metallic luster than the

other, both appear somewhat porous, and the gold can be removed by moderate abrasion.

SEM 5: Each foil is uncoated 0.0003" aluminum. One surface is specular, the other is dull in appearance. An observed difference in emissivity of 1.0 - 1.5% for all SEM's when the monitors are oriented in opposite directions in the beam may be caused by this difference in foil surface.

SEM 6: Each foil is 0.0003" aluminum coated with gold ($\sim 1000 \text{ \AA}$) on each side by a different vacuum-evaporation method than used for SEM 4. These gold surfaces have a more compact quality than in SEM 4. One surface has more luster than the other, and the gold cannot be removed from either surface by abrasion.

Performance

Under normal operating conditions, odd-numbered foils are negatively biased. Even-numbered foils are at ground potential and serve as charge collectors. In this arrangement secondary electrons that originate in the end windows are shielded from the collectors by the high voltage plates.

The fringing field produced by the permanent magnet of the Vacion pump can affect the sensitivity of the CEA SEM's. A higher bias voltage is necessary to overcome this

effect. The curves in Fig. 3 show the dependence of SEM response on beam position for various bias voltages. A bias of -1000 V has been chosen to assure flatness of response and has been subsequently used for all SEM's.

As observed by previous investigators, practically all secondary electrons are collected when the electric field between the foils is -50 V/cm. The bias curve representing the variation of response with voltage is shown in Fig. 2. In agreement with earlier observations², the main features of this curve are:

1. With identical beam conditions, the charge collected when the SEM is biased positively is 2 - 3% larger (in absolute value) than when it is biased negatively.
2. The sensitivity decreases by about 1% per hundred volts in the plateau-like region.
3. A small positive residual charge is collected with zero bias. This corresponds to a loss of electrons that are ejected in the forward direction with sufficient energy to traverse all foils.

Since most secondary electrons have energies less than 50 eV, it follows that secondary emission is a surface phenomenon³ that is limited to a layer of about 100 Å in thickness. Therefore the yield should be essentially independent of the foil thickness. It has been known for some time that, for a given metal, the surface condition plays a definite role in determining the secondary emission yield. The time required

for "conditioning" a surface of a chemically inert metal such as gold is shorter than it is for a chemically active metal such as aluminum. Conditioning is usually achieved by exposing the monitor to the beam prior to its actual use. With gold the response becomes constant almost instantly, whereas with aluminum an exposure of 20 - 30 minutes in the beam is required before equilibrium is reached. In Fig. 4 is shown the variation of the response of aluminum with time (starting from an arbitrary time) at CEA and at SLAC. Each point represents an average value of the response during the time required to make the measurement (~ 1 min).

This time dependence is attributed⁴ to the Malter effect⁵ in which the electric field of the positive charge that accumulates on the polarized oxide coating of the foil induces increased electron emission from the metallic surfaces.

As stated above, secondary emission is primarily a surface effect. Low energy electrons that are produced at a depth greater than a critical value are absorbed before they can diffuse to the surface. For a fixed diffusion length and a given beam cross section, the number of atomic electrons that lie in the beam within a distance δ of the surface depends on the angle of beam incidence and is proportional to $1/\cos \theta$. In Fig. 5 the response of a SEM for various angles of beam incidence is compared to $1/\cos \theta$ for both positive and negative biases.

The response of gold-plated secondary emission monitors has been found to be independent of the average beam intensity (see Fig. 6), spill length, duty cycle, and pulse repetition rate. Furthermore, long-term reproducibility is $\approx 0.5\%$ or better (see Fig. 7), providing that the geometry of the beam path remains constant.

All SEM's are normally calibrated against a Faraday cup. Since secondary emission is induced by charged particles of either polarity, the response of a SEM depends on its location and on the amount of material in the beam path (see Fig. 8). An electron-positron pair produced in this material, while detected by a SEM, contributes no net charge to the Faraday cup. The constancy of the ratio $q_{\text{SEM}}/q_{\text{FC}}$ during an experimental run thus yields a sensitive and simple indication of beam tuning.

Discussion and Interpretation of Results

The measurements to be discussed herein cover the energy range of 1.5 to 6 GeV with electrons at CEA, and 3 to 18 GeV with electrons and 6 to 11 GeV with positrons at SLAC. In all of these measurements, the Faraday cups used at CEA¹ and at SLAC⁶ were assumed to be 100% efficient, absolute monitors of beam charge. Limited experimental information on measured calibrations of Faraday cups (by null method⁷ and by calorimetric method⁸) supports this assumption. An experimental comparison by means of a CEA secondary emission

monitor showed⁹ that the CEA and SLAC Faraday cups are equivalent to within 1.001 ± 0.003 at 3 GeV.

The energy dependence of the secondary emission yield, in the energy range mentioned above, is given in Fig. 9 for aluminum (SEM 5) and in Fig. 10 for gold (SEM 4 and SEM 6). In the case of aluminum, measurements made at CEA and at SLAC in overlapping energy regions exhibit nearly the same slope, even though they differ in magnitude by 1.0 - 1.5%. For convenience of analysis, the CEA data were normalized at 3 GeV to the SLAC data simply because the latter cover a broader energy range and were taken over a shorter interval of time. The difference in the emissivity between the two sets of measurements may be due to differences in surface conditioning or to inherent differences in instantaneous beam current densities at the foil surface associated with the pulse characteristics of the two accelerators (1.5 μ sec at SLAC and 100 - 500 μ sec at CEA).

No measurement of the intensity dependence of secondary emission from SEM 5 (aluminum) has ever been made.

A significant difference (14.5%) in the secondary emission yield from gold had been observed between SEM 4 and SEM 6 at CEA. We attribute this difference to dissimilar surface characteristics introduced through the coating processes. During the time that these surfaces were maintained under continuous vacuum, the response of each monitor

remained stable and reproducible within 0.3 - 0.5% while differing from each other by 14.5%. However a temporary leak that developed in SEM 4 during shipment to SLAC resulted in a permanent change in its emissivity. The subsequent responses of the two units have agreed to within 1.3%. This difference in response of the two units may have resulted from the foils having been exposed to air for different periods of time after the evaporation process. For SEM 4 this exposure was a few hours, but for SEM 6, for which the evaporation was done commercially, the exposure was several days. The vacuum leak in SEM 4 would thus have equalized the exposure to air and would possibly have equalized the responses of the two monitors.

By integrating the Møller cross section over the thickness of the foil, Tautfest and Fechter¹⁰ have derived a simple expression for the secondary emission yield:

$$Y = \frac{4\pi r_e^2 N Z}{AK\beta^2} \xi^{\frac{1}{2}} \quad (1)$$

where r_e is the classical radius of the electron, N is Avogadro's number, Z and A are the atomic number and weight of the foil material respectively, ξ is the thickness of the foil in g/cm^2 , K is the constant in the range-energy relation, and β is the ratio v/c for the incident particle. At higher energies, the $1/\beta^2$ dependence makes this yield independent of energy, and this was confirmed by their measurements in the interval 111 to 235 MeV. Energy independent

results have also been reported for other energy intervals¹¹. However other results for aluminum have indicated a definite energy dependence throughout the range 0.5 MeV to 5.0 GeV¹².

It is commonly understood that secondary emission refers to all low energy electrons ejected from a foil by the passage of a primary particle. In a more refined theory of secondary emission, Vanhuyse and Van de Vijver¹³ consider Møller scattering of electrons from the primary beam with subsequent diffusion into and absorption by the foil medium. The number of electrons that leave the foil surface consists of scattered secondaries that have lost energy in the foil and of tertiaries that have been ejected by interactions between the secondaries and atomic electrons.

According to those authors, the energy dependence of secondary emission results from the tertiary electrons. Above a few MeV, the total yield of electrons has a simple logarithmic energy dependence:

$$Y(E, \xi) = G(\xi) + \alpha \ln(E) \quad (2)$$

The function $G(\xi)$ depends on foil thickness but is essentially independent of energy in this region.

The logarithmic energy dependence of the yield of a three foil SEM (two collecting surfaces) is characterized by the slope α ,

where:

$$\alpha = \frac{4BE_F^{3/2} \delta NZ}{\phi a \sigma A m_0 c^2} \quad (3)$$

In the above relation, B is a constant, E_F is the Fermi energy, $\delta NZ/A$ is the number of electrons/cm³, ϕ is the work function, a is a material dependent constant, and σ is the absorption coefficient for electrons diffusing in the medium.

All available data for aluminum, including those of the present experiment, are given in Fig. 11. Despite the fluctuations that are characteristic of aluminum, most of the previous measurements indicate that α is nearly constant in the energy interval 10-600 MeV. Above 1.0 GeV, as indicated by the data of this experiment, the departure from a logarithmic dependence increases with energy, and in the interval 1.5 to 18 GeV, the value of α_{Al} decreases by almost an order of magnitude.

The data for gold agree more closely with Eq. 2. The energy dependence is logarithmic in the interval 1.5 to 8 GeV (see Table 1).

	CEA	SLAC
SEM 4	$\alpha = 9.0 \times 10^{-3}$	$\alpha = 7.2 \times 10^{-3}$
SEM 6	$\alpha = 6.0 \times 10^{-3}$	$\alpha = 6.0 \times 10^{-3}$

TABLE 1. YIELD SLOPE α FOR GOLD

As mentioned above, the response of SEM 4 changed after a vacuum leak developed during shipment to SLAC. This change is evident in the value of α for SEM 4 in Table 1. If the straight line representing the secondary emission yield at lower energies in the energy range 1.5 to 18 GeV is extrapolated, the maximum departure from a $\ln(E)$ dependence at 18 GeV is 6.8% for gold and 31% for aluminum.

As mentioned above, the efficiency of the SLAC Faraday cup used in these measurements was assumed to be 100% at all energies. Additional measurements taken simultaneously with a toroid charge monitor¹⁴ displayed an inconsistency outside the limits of experimental uncertainties which would result in an increased departure from a logarithmic dependence. The ratio $q_{\text{tor}}/q_{\text{FC}} = 1.02$ remained constant from 3 to 13 GeV. At 18 GeV, this ratio increased to 1.03. It is assumed that the response of the toroid charge monitor depends only on the charge passing through it and is independent of the beam energy; hence this measured increase is consistent with a decrease of Faraday cup efficiency at 18 GeV. If this is indeed the case, the measured value of $q_{\text{SEM}}/q_{\text{FC}}$ would have to be corrected, and the departure from a $\ln(E)$ dependence would become even more pronounced.

In computing α from Eq. 3, Vanhuyse and Van de Vijver used the value of σ for nickel (the only measured value available). The value thus obtained was $\alpha = 1.4 \times 10^{-3}$.

This is to be compared to the value of $\alpha = 2.2 \times 10^{-3}$ obtained by Vanhuyse and Van de Vijver from the data of Bumiller and Dally^{12,1}. A test of the adequacy of this theory would be the accuracy to which α_{Al} and α_{Au} could be predicted. Without appropriate values of σ , this test cannot be made.

If all of the energy dependent data^{12a-f} are combined, the energy dependence of the secondary emission yield bears a marked similarity (minimum at 1 - 2 MeV and logarithmic increase at higher energies) to the energy dependence of the Bethe-Bloch formula¹⁵:

$$\frac{dE}{dx} = \frac{2\pi n e^4 Z}{m_0 c^2 \beta^2} \left| \ln \left(\frac{2m_0 c^2 \beta^2 \eta}{I^2 (1-\beta^2)} \right) - \beta^2 \right| \quad (4)$$

where n = number of atoms per cm^3 .

I = Ionization potential (100 eV for Al, 870 eV for Au)

η = the maximum energy transfer per collision

and all other symbols have their usual meaning.

Both Eq. 3 and Eq. 4 have a logarithmic dependence on energy. This should be expected since in both cases the energy transfer results from the same process -- the Coulomb interaction between the incident and atomic electrons.

Aggson⁴ has developed a qualitative theory of secondary emission in which the energy dependence is predicted by suitably modifying the Bethe-Bloch formula. In his formulation,

secondary emission is confined to the upstream and downstream surfaces of the foils. Different conditions are operative at these surfaces. At the downstream surface, it is assumed that the density effect limits the energy loss, while at the upstream surface, the density effect is assumed to be of no importance. These assumptions are based on the following reasoning: the density effect results from cancellation of the field of the incident particle at large distances by collective redistribution of electrons near its trajectory¹⁶. Such collective motion is related to the plasma frequency of the medium.

The distance traversed by a highly relativistic electron during one period of the plasma oscillation is $\sim 100 \text{ \AA}$. This distance is much less ($\approx 10^{-3}$) than the foil thickness, and the foil appears in effect as a medium semi-infinite in extent. Hence the energy loss is limited by the density effect at the downstream surface. At the upstream surface, the electron approaches from a vacuum. The electric field of a highly relativistic particle approximates an impulse purely transverse in nature. The transverse extent of the impulse at the foil surface is not limited by the density effect (since the particle is in vacuum), and hence secondary emission from this surface is energy dependent. The effective impact parameter for collisions increases with γ :

$$b_{\text{max}} \leq \frac{\hbar \beta c \gamma}{I} \quad (5)$$

According to Ter-Mikaelyan¹⁷, the length of trajectory, L, associated with this impact parameter also increases:

$$L = b_{\max} \gamma \sim \gamma^2 \quad (6)$$

At high energies, L can become comparable to the foil spacing in the SEM. Then the electric field cannot be fully established as the particle traverses the interfoil space, and the energy loss can deviate from a $\ln(E)$ dependence.

Aggson modified the Bethe-Bloch relation by limiting the maximum value of γ^2 in Eq. 4. At the upstream surface, γ^2 is limited by the foil spacing t:

$$\gamma_{\max}^2 \rightarrow \frac{1}{\left(1 - \beta^2 + \frac{\hbar c}{tI}\right)} \quad (7)$$

and at the downstream surface, γ^2 is limited by a density effect term:

$$\gamma_{\max}^2 \rightarrow \frac{1}{\left(1 - \beta^2 + \beta^2 \frac{4\pi n e^2 \hbar^2}{m_0 I^2}\right)} \quad (8)$$

By averaging the contributions from the upstream and downstream surfaces, Aggson obtained an expression for the energy dependence of secondary emission monitors:

$$\text{Emiss} \sim \frac{2\pi n e^4 Z}{m_0 c^2 \beta^2} \left[\ln \left(\frac{2m_0 c^2 \beta^2 \eta}{I^2 \left(1 - \beta^2 + \frac{\hbar c}{tI}\right)^{\frac{1}{2}} \left(1 - \beta^2 + \beta^2 \frac{4\pi n e^2 \hbar^2}{m_0 I^2}\right)^{\frac{1}{2}}} \right) - \beta^2 \right] \quad (9)$$

The energy dependence (after normalization to the data at 1.5 GeV) of Eq. 4 and Eq. 9 is compared to our data from 1.5 to 18 GeV for aluminum in Fig. 9 and for gold in Fig. 10. Although Eq. 9 predicts a departure from a logarithmic dependence at higher energies, this deviation is more pronounced than that which is evident from our data. For a given value of η , a better fit can be obtained by varying t . Reasonable fits to the data were obtained for $t = 10$ cm for aluminum and for $t = 100$ cm for gold. Use of t other than the actual foil spacing of $t = 1.27$ cm is not physical. However this variation was performed to investigate the adequacy of the formulation of Eq. 9.

The value of the interaction energy η was also varied with $t = 1.27$ cm. Perfect fits to the data could be obtained by varying η with beam energy. The value of η required to fit the data at 1.5 GeV was assumed to be 10^4 eV. The value of E_{miss} from Eq. 9 was normalized to the experimental data at this energy. Although $\eta = 10^4$ eV is equal to the value used by Aggson and is consistent with the estimate of 10^4 to 10^5 given by Rossi¹⁵, it is much larger than the value that would be predicted using the following argument.

The relativistic increase of the energy loss results from interactions at large impact parameters. In his discussion of the energy loss problem, A. Bohr¹⁶ indicated that a classical approach gives a good approximation as long as the momentum transfer is much smaller than the

momentum of the incident particle. This condition is certainly satisfied for distant collisions. For these collisions, the impulse imparted to the atomic electrons is independent of the incident energy. However the transfer of energy depends upon whether or not the atomic electrons respond adiabatically to this impulse.

As the energy of the incident particle increases, the time during which the impulse occurs becomes less than the period of the plasma oscillation of the medium, the electrons cannot respond adiabatically, and energy is transferred to the atomic electrons.

At 1.5 GeV, the value of Eq. 9 is nearly twice that at the point of minimum energy loss ($E \sim 1$ to 2 MeV). Thus the contribution from distant collisions is of primary importance at high energies. Since in these collisions the average energy transfer is far less than 1 eV, use of $\eta = 10^4$ in Eq. 9 seems unjustified. The dependence of Eq. 9 on η is compared to the experimental data in Fig. 12 for aluminum and in Fig. 13 for gold. A particularly good fit is obtained for aluminum with $\eta = 0.01$ eV. The fit to the gold data is not as good. In both cases, the estimated interaction energy of 0.002 eV (for an atomic radius of 1.4 to 1.5 Å) results in values greater than the data. In view of the crudeness of this approximation (the energy independent contribution was set equal to the minimum value of Eq. 9 for arbitrary η

{this minimum value probably results from near collisions for which η should be of the order of 10^4 eV} and the necessity to normalize the data if the Faraday cup has an energy dependence), the fit of Eq. 9 to the data, if not exact, at least appears reasonable.

A special three-foil SEM was constructed in which the spacing between the collector and one of the high voltage foils could be changed while the monitor was evacuated. Measurements of the response of the SEM were made at 5.5 GeV with the movable foil oriented both upstream and downstream in the beam. The bias on the fixed high voltage foil was maintained at either zero or 800 V/cm, while the bias on the movable foil was adjusted according to the foil position.

Response curves for both positive and negative biases were measured for foil spacings of 1, 2.5, 5, 10, and 20 mm. The two most important characteristics of the response curves are:

1. The ratio $q_+/q_- < 1.0$ (0.69 for the foil upstream and 0.82 for the foil downstream, where for all other SEM's $q_+/q_- > 1.0$). The electric field intensity and the foil spacing during the above measurement were the same as those used in standard SEM's. Hence the departure of the ratio q_+/q_- from the value measured for the other SEM's must at this time be attributed to the difference in the number of foils (any end effects would be much

more noticeable in a three foil SEM than they would in a nine foil SEM).

2. The response of the SEM decreases as the foil spacing increases, see Fig. 14. According to Aggson's theory, the response of a SEM should become constant when the field forming distance exceeds the foil spacing. By reducing the foil spacing from the standard 12.7 mm to nearly one millimeter, the conditions equivalent to 18 GeV with a standard foil spacing should have been simulated. Instead of observing a decrease in SEM response as the foil spacing was decreased, we observed an increase! This trend was reproduced when the moveable foil was changed from the upstream to the downstream orientation.

Bakhshyan and Garibyan have considered the response of secondary emission monitors from a theoretical aspect¹⁹. Assumed in their treatment is the presence of a thin dielectric coating on the foils. Low energy electrons emanating from the foil proper have insufficient energy to penetrate the dielectric layer. Hence the contribution from the metal foil consists of forward scattered electrons with minimum energies of several KeV. These electrons result from close collisions, and hence the Møller cross section need not be modified for the density effect. This contribution to the secondary electron current is independent of the energy of the incident particle.

There is also a contribution to the yield of secondary electrons that originates in the dielectric coatings of the foils. This contribution is not limited by the density effect as long as the layer is thin or as long as there is a strong electric field in the layer. This contribution should increase as $\ln(E)$.

The above authors give as a criterion for the presence of a dielectric layer the decrease of the SEM response as the SEM bias is increased. We observe this change of response for both aluminum and gold. (Some observers report bias curves that do not decrease with increasing bias. This is true both for electrons^{8, 10, 11a} and for protons^{20, 21}.) Our criterion for the presence of a dielectric layer, the change of SEM sensitivity with time, see Fig. 4, is not observed for gold. Thus if a dielectric layer exists on the gold, the time required for the surface charge to reach equilibrium would have to be shorter than that which we could easily measure (less than ~ 1 min).

Positrons

Measurements of secondary emission yields for high-energy positrons were performed with aluminum and gold at 6 and 11 GeV at SLAC. The beam characteristics were maintained identical to those of the electron beam except that the maximum available intensity was limited to $2 \times 10^9 e^+$ /pulse. At these energies, the measured yield from aluminum

and gold with positrons was higher than the yield with electrons at the same energy by at most 1% (see Fig. 9 and Fig. 10).

The consistency check provided by the toroid charge monitor¹⁴ for electrons was also made during the positron run. With all experimental conditions remaining constant, the ratio $q_{\text{tor}}/q_{\text{FC}} = 0.96$ did not change with energy (the response of the toroid had remained constant during bench tests in which an electron current was passed through the toroid in both the forward and backward directions).

If one assumes that the ratio $q_{\text{tor}}/q_{\text{FC}} = 1.02$ for electrons results from a 2% bias of the toroid, normalization of the ratio $q_{\text{tor}}/q_{\text{FC}} = 0.96$ for this bias would still leave a discrepancy of 2% remaining in the ratio²². If one further assumes that $q_{\text{tor}}/q_{\text{FC}}$ is independent of the polarity of the beam charge (as was shown in bench tests), the apparent efficiency of the Faraday cup for positrons would be 2% greater than for electrons. Upon further normalization, this would indicate that the secondary emission yield from aluminum and gold with positrons is higher by about 3% than with electrons.

Summary

The response of aluminum and gold secondary emission monitors has been measured from 1.5 to 18 GeV for electrons and at 6 and 11 GeV for positrons. The secondary electron

yield in a positron beam was found to be 1 to 3% larger than in an electron beam. Dependence of SEM response on the angle of the beam from normal incidence was found to vary as $\sec\theta$. For energies below 8 GeV, the response of both types of monitors varies nearly as $\ln(E)$. However in the range 1.5 to 18 GeV, the deviation from a $\ln(E)$ dependence is 6.8% for gold and 31% for aluminum.

Attempts of correlating the measured energy response to the theory of Vanhuyse and Van de Vijver indicate that the yield slope (predicted to be independent of energy) varies by nearly an order of magnitude in this energy range.

A departure of SEM response from a $\ln(E)$ dependence is predicted by the theory of Aggson. Use of an interaction energy of $\eta = 10^4$ produced a more pronounced deviation than is evident from our data. Based on the argument that the $\ln(E)$ dependence results from distant collisions, η was varied to include values that are more realistic for these distant collisions, and reasonable fits to the data were obtained for $0.01 \leq \eta \leq 0.1$ eV. A further test of Aggson's theory was made by measuring the response of a SEM in which the foil spacing could be varied. It was found that the monitor response increased with decreasing foil spacing. This is contrary to the predictions of Aggson's theory.

Finally mention was made of the theoretical treatment of Bakhshyan and Garibyan in which the energy dependence

of SEM's is attributed to the presence of a thin dielectric layer on the foil surfaces. Whereas Aggson predicts that the energy dependence results from the upstream foil surfaces and that departure from a $\ln(E)$ dependence is a consequence of finite foil spacing, Bakhshyan and Garibyan assert that the energy dependence results either from the total absence of the density effect in thin dielectric layers or at least from an increase in the energy at which the density effect becomes significant in thin dielectric layers. Tests of these assertions are still to be made.

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FIG. 1a STRUCTURE OF CEA SECONDARY EMISSION MONITOR

FIG. 1b INTERNAL STRUCTURE OF CEA SECONDARY EMISSION MONITOR

FIG. 2

BIAS CURVE FOR SEM 6 AT 1.8 GeV

FIG.3 DEPENDENCE OF SEM RESPONSE ON BEAM POSITION

FIG. 4 VARIATION OF ALUMINUM RESPONSE WITH TIME

FIG.5 DEPENDENCE OF SEM RESPONSE ON ANGLE OF BEAM INCIDENCE

FIG. 6 DEPENDENCE OF SEM 4 RESPONSE ON BEAM INTENSITY

FIG.7 TIME DEPENDENCE OF SEM
RESPONSE AT 3GeV (bias-1000V)

FIG. 8 DEPENDENCE OF MONITOR RESPONSE ON ABSORBER IN BEAM (CEA)

FIG.9 ENERGY DEPENDENCE OF SECONDARY EMISSION YIELD FROM ALUMINUM

FIG. 10 ENERGY DEPENDENCE OF SECONDARY EMISSION YIELD FROM GOLD

FIG. II VARIATION OF α WITH ENERGY FOR ALUMINUM AND GOLD

FIG. 12 COMPARISON OF AGGSON'S THEORY TO ALUMINUM DATA

FIG. 13 COMPARISON OF AGGSON'S THEORY TO GOLD DATA

FIG. 14 SEM RESPONSE FOR VARIABLE FOIL SPACING

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