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A COMPARISON OF CEA AND SLAC FARADAY CUP CALIBRATION BY MEANS OF A SECONDARY EMISSION MONITOR

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY
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CAMBRIDGE ELECTRON ACCELERATOR

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A COMPARISON OF CEA AND SLAC FARADAY CUPS BY MEANS OF A SECONDARY EMISSION MONITOR

Introduction

In comparing the experimental results from different laboratories, it is desirable that a comparison also be made of the monitoring devices used to determine the number of particles in the beam. In each laboratory the Faraday cup is considered as the standard for direct calibration of charged particle monitors and for indirect calibration of photon monitors. The comparison described below of the CEA and SLAC Faraday cups is based on data from a twenty-four hour run on March 25, 1968, at SLAC and data accumulated over a period of time in excess of one year at CEA.

The choice of secondary emission monitors (SEM) as satisfactory intermediate monitors for intercalibration purposes was determined by the following factors: (i) very good stability and reproducibility (to within 0.1 - 0.3%) measured over long periods of time (6 months or more), (ii) independence of response with pulse length and repetition rate, and (iii) ease of transportation.

The secondary emission monitor (CEA SEM 6) used during the present measurements* has the same mechanical characteristics as that used for the calibration of CEA quantameters.[1] It consists of nine 0.0003" Al foils plated by evaporation with about 1000 Å of Au per surface and mounted on 10.5" I.D. rings (see Fig. 1). The vacuum enclosure includes two 0.003" stainless steel windows of the same diameter and a permanently incorporated 8 liter/sec titanium-discharge Vacion pump. Because of satisfactory seals and careful handling, good vacuum was preserved without actual pumping during transportation from CEA to SLAC and back. The normal base pressure of almost 2×10^{-8} torr was readily obtained when pumping was resumed. The stability in time of the response of SEM 4 and SEM 6 at 3 GeV is shown in Fig. 2.

The electron beam runs used at CEA (External Beam Area #7), and at SLAC (End Station A) were made to have as nearly as possible identical geometries and dimensions (Fig. 3). A list of beam run characteristics is given in Table I, and the detailed structures of the CEA and SLAC[2] Faraday cups are shown in Fig. 4.

*Measurements with two other monitors, SEM 4 and SEM 5, were made during this run. A vacuum leak developed in SEM 4 during transit. The subsequent sensitivity of this monitor decreased by 14.6%, and thus it could not be used for purposes of comparison. Unlike SEM 4 and SEM 6, SEM 5 has unplated aluminum foils. Although the lack of reproducibility characteristic of aluminum made it unsuitable for purposes of comparison, it was used to study the energy dependence of secondary emission from aluminum.

Having previously observed a 1.5% difference in secondary emission associated with the orientation of the SEM in the beam, care was taken to give the monitor the same positioning in both beams. An important difference between the two runs appears in the shielding geometry. At the CEA the Faraday cup (No. 1) is enclosed in a shielding hut (4-ft. thick ilmenite-loaded concrete wall with an 8" x 8" aperture for the beam entrance) built on the experimental floor. At SLAC the Faraday cup is unshielded. Both Faraday cups have their own pumping systems and have been under pressures of the order of 10^{-7} - 10^{-6} torr during the measurements. No contribution from residual ionization is to be expected at this pressure.

Performance

Most measurements for intercalibration purposes were performed at 3 GeV, an energy for which data have been accumulated at CEA with the same beam run geometry during a period of more than one year.

(a) Beam Size

The beam transport systems for bringing the electron beam to the experimental area have different configurations at CEA and at SLAC. The normally small cross section of the electron beam at SLAC (1 - 3 mm^2) was defocussed to match the beam size used during the CEA measurements (6 - 10 mm^2) in order to eliminate possible variations in secondary emission attributable to high local electron densities.

(b) Integrators

Because of marked differences in pulse characteristics of the two beams under discussion (see Table I), it was indispensable to compare the performance of integrators used at CEA and SLAC. These integrators differ in construction and mode of operation. (i) at CEA: the input charge is integrated by a Miller amplifier, the output of which at a preset level triggers a discriminator which in turn enables a known charge of opposite polarity to be fed from a reference capacitor to the amplifier input, thereby restoring the latter to its initial condition[3]; (ii) at SLAC: they consist of commercial vibrating-reed electrometers (Cary 31) with added precision-calibrated input capacitors.[2]

In order to ascertain that no alteration of performance was introduced during transportation, the calibration of the CEA integrators was confirmed by means of a portable device in which the calibrating dc current is determined by the magnitude of a precision resistor placed in series with a Zener diode voltage source. When the voltage across the integrator input is vanishingly small, the precision voltage source becomes a precision current source. This system has been compared to a laboratory precision current source and, after corrections for ambient temperature and line voltage, proved to be accurate to within 0.2 - 0.3%.

The responses of two CEA gold-plated SEM's in the SLAC run were measured with both CEA and SLAC integrators. The average values and the corresponding standard deviations thus obtained are:

	CEA Integrators	SLAC Integrators
$q_{FC}/q_{SEM\ 4}$	3.137 ± .003	3.131 ± .001
$q_{FC}/q_{SEM\ 6}$	3.121 ± .001	3.117 ± .001

The agreement between these measurements for a given SEM is thus 0.2% or better. This is within the accuracy given for the absolute calibration of the CEA integrators. All subsequent measurements were taken exclusively with CEA integrators.

(c) Repetition Rate

The repetition rate at SLAC was varied between 10 and 180 pps. The extent to which the CEA integrators are insensitive to pulse rate within this range is shown by the following results:

Rep Rate (pps)	10	60	180
$q_{FC}/q_{SEM\ 6}$	3.128 ± .001	3.121 ± .001	3.118 ± .001

These measurements can be considered constant within 0.3%. It should be borne in mind that the upper limit for overall stability and absolute accuracy of the CEA integrators is given[3] as 0.3% for the ranges 10^{-6} - 10^{-8} Coulomb used in these measurements.

(d) Background

It has been stated[2] that the SLAC electron beam (in End Station A) has a certain "beam halo" probably caused by upstream collimation and consisting primarily of low-energy photons. To assess the extent to which the Faraday cup and the SEM are sensitive to such possible contamination, a measurement was taken with the electron beam deflected downward and completely absorbed (in A-Beam Dump). The charges collected during this test in both the Faraday cup and the SEM represent less than 1.5×10^{-5} and 2.5×10^{-5}, respectively, of the normal charge collected during equal times and identical beam conditions. The fact that the SEM now seems more sensitive (by a factor of about 2) to this neutral background relative to the Faraday cup is probably attributable to photo-emission phenomena taking place in its more extensive surface exposed to the beam and induced by synchrotron radiation (from the dump magnet) and by low-energy photons.

(e) Absorber

The presence of an absorber in the beam induces effects which can be helpful in attempting to normalize the electron beam runs at CEA and at SLAC. In both runs an absorber of variable thickness t was located upstream of the SEM (position A) and between the SEM and the Faraday cup (position B).* The responses corresponding to these cases in both beam runs at 3 GeV are shown in Fig. 5 (CEA) and in Fig. 6 (SLAC). While the trends are roughly similar, it is interesting to note that the more detailed behavior is not the same in both beam runs:

1. Position A (upstream of SEM). Both members of an $e^- - e^+$ pair produced in the absorber cause secondary electrons

*Two different SEM's (No. 4 and No. 6) were used in these measurements, but their construction is identical.

to be ejected from the SEM foils, but they contribute no net charge in the Faraday cup. This thus leads to a more substantial decrease in the ratio q_{FC}/q_{SEM} when t increases, as observed both at CEA and SLAC. The more rapid decrease when the absorber is nearer the SEM (position A' in Fig. 5) is the result of more secondaries being intercepted by the larger solid angle subtended by the SEM at the absorber. The small (0.8%) increase of this ratio for $t < 1.4 \times 10^{-2}\ X_o$ at SLAC may be due to the removal from the beam of a low-energy component which was observed when the beam is diverted into the beam dump, as discussed above.

2. Position B (between SEM and Faraday cup). The change in response of the SEM and Faraday cup is much smaller than in the previous case, but while the ratio q_{FC}/q_{SEM} increases by 0.42% at SLAC, it decreases by 0.37% at CEA for a total thickness $t = 0.142\ X_o$ in the beam. This may seem contradictory, but one should remember that: (i) the re-entrant well of the CEA Faraday cup has different characteristics (8.8" dia., 8" deep, 0.79 sterad) from those of the SLAC cup (5" dia., 15" deep, 0.085 sterad) resulting in more loss of charge through back scattering; (ii) the "heat plug" is of higher Z material at CEA (W) than at SLAC (Cu) which also leads to more back scattering at CEA; (iii) the Faraday cup entrance aperture is much smaller at SLAC (about 4.5" dia.) than at CEA (about 8.8" dia.) so that it intercepts a smaller fraction of the shower developed in the absorber and may introduce additional edge effects.

As a final check in comparing the two beam runs and Faraday cups, the energy dependence of SEM 6 emissivity was determined at both laboratories. With the exception of the 5.5 GeV point at CEA, all points at CEA and SLAC fit accurately the same ln(E) curve (Fig. 7).

At 3 GeV, the ratio (q_{FC}/q_{SEM}) is 3.118 ± 0.004 at CEA, whereas at SLAC, including a 0.1% correction for difference in path length, it is 3.120 ± 0.001. A comparison of this ratio at SLAC and at CEA, including an indeterminacy of 0.2% at each laboratory arising from the uncertainty in absolute calibration of the integrators is:

$$\frac{(q_{FC}/q_{SEM6})\ \mathrm{SLAC}}{(q_{FC}/q_{SEM6})\ \mathrm{CEA}} = 1.001 \pm 0.003$$

We conclude that for the experimental geometry used, the responses of the SLAC and CEA Faraday cups agree to within 0.4% at 3 GeV. No attempt for absolute calibration of the Faraday cups has been made in this comparison.

One may infer that, unless a fluctuation in beam characteristics occurred during the measurements, a discrepancy appears in the constancy of response with energy of the CEA Faraday cup by 1.3 ± 0.1% in the energy range 5 - 6 GeV. More measurements will be taken to clarify this question.

Acknowledgement

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References

[1] G. F. Dell and M. Fotino, Proceedings of the Symposium on Beam Intensity Measurement, Daresbury Nuclear Physics Laboratory, Daresbury, England, April 22-26, 1968; CEA Report CEAL-1040, May 1, 1968.

[2] D. Yount, Nucl. Instr. & Methods, 52, 1 (1967).

[3] L. A. Law and J. Weinstein, CEAL-1021, May 14, 1965.

TABLE I

SLAC		CEA	
BEAM RUN			
Č Monitor	3.14 mX_o		
Ion Chamber	.95 mX_o		
SEM	3.0 mX_o		
Air (3 ft.)	3.0 mX_o		
Ion Chamber	1.41 mX_o		
Flap Valve	.14 mX_o	Target Entrance Window	.6 mX_o
Target Exit Window	2.27 mX_o	Target Exit Window	2.8 mX_o
Air	13.8 mX_o	Air (15 ft.)	15.0 mX_o
SEM	9.6 mX_o	SEM	9.6 mX_o
Air	22.8 mX_o	Air	15.0 mX_o
Total	60.11 mX_o		43.0 mX_o
FARADAY CUPS			
F.C.Window 10 mil AL	.3 mX_o	F.C.Window 3 mil s.s.	4.2 mX_o
C Plug	.2 X_o	½" AL	.14 X_o
Cu Plug	19.5 X_o	2" W	14.1 X_o
Pb Body	51.0 X_o	11" Pb	54.8 X_o
Fe Case	1.4 X_o		
	72.1 X_o		69.04 X_o
Radius	46.0 X_o	Radius	67.2 X_o
Well	5" dia. x 15" deep	Well	8-7/8" dia. x 8" deep
Solid ∠ for Back Scatter	.085 STR	Solid ∠ for Back Scatter	.792 STR
Magnets	250 Gauss x 3"	Magnets	250 Gauss x 3-3/4"
Escape Energy	1.5 MeV	Escape Energy	0.55 MeV
BEAM CHARACTERISTICS			
Rep Rate	60 pps	Rep Rate	60 pps
Spill Length	1.5 μsec	Spill Length	100-500 μsec

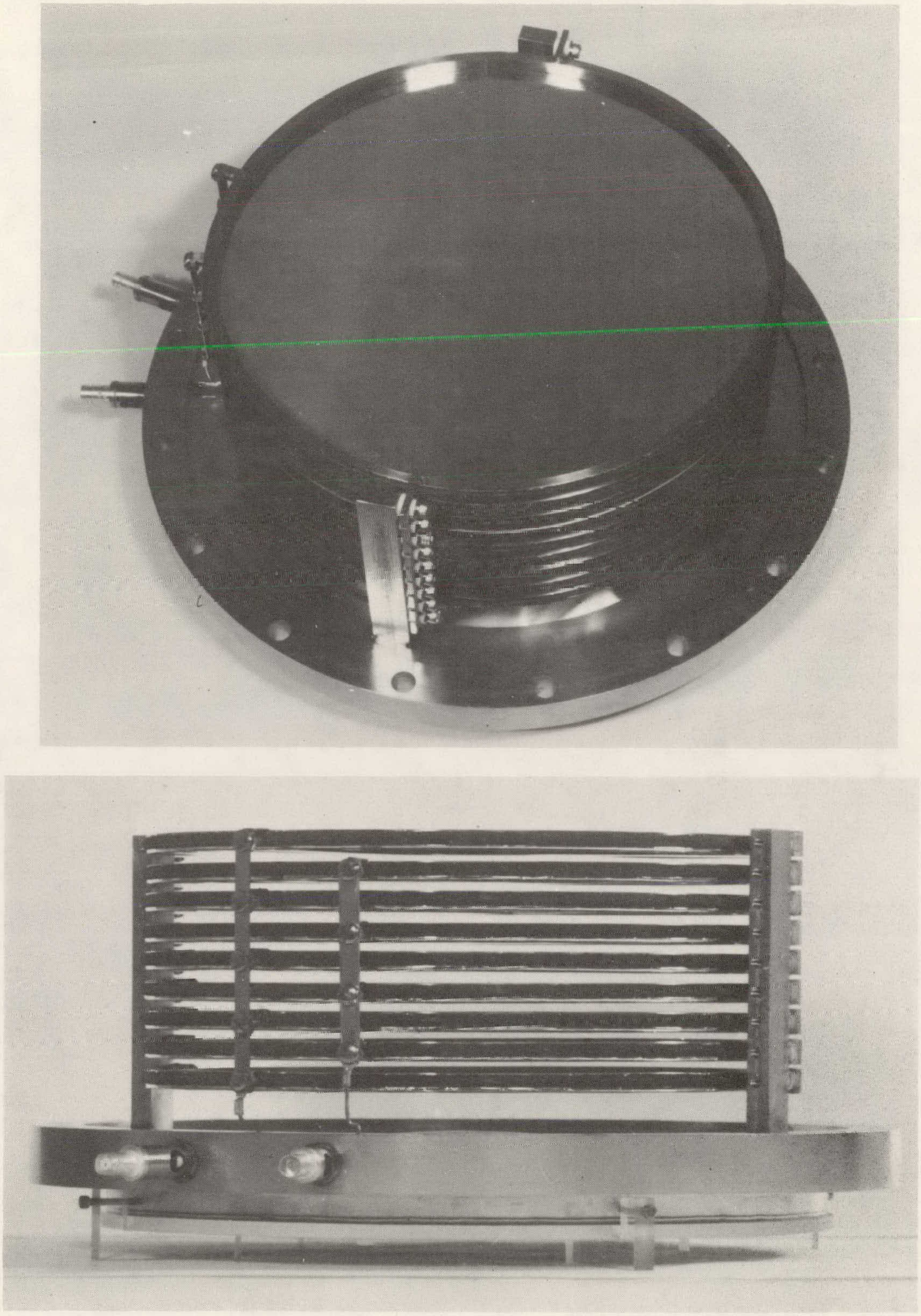

FIG. 1 - STRUCTURE OF THE CEA SECONDARY EMISSION MONITOR

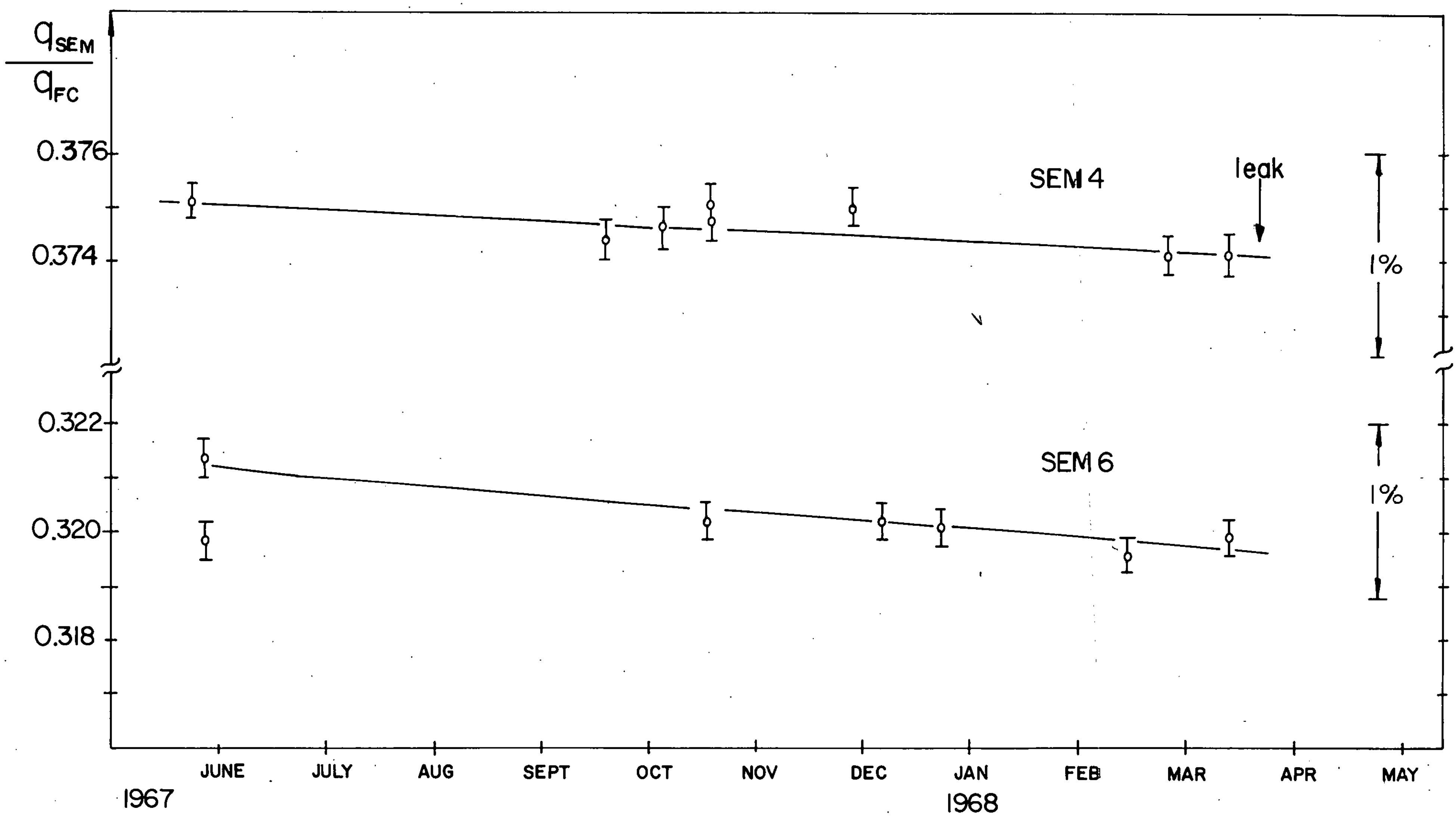

FIG. 2 - TIME DEPENDENCE OF SEM RESPONSE AT 3GeV (bias-1000V)

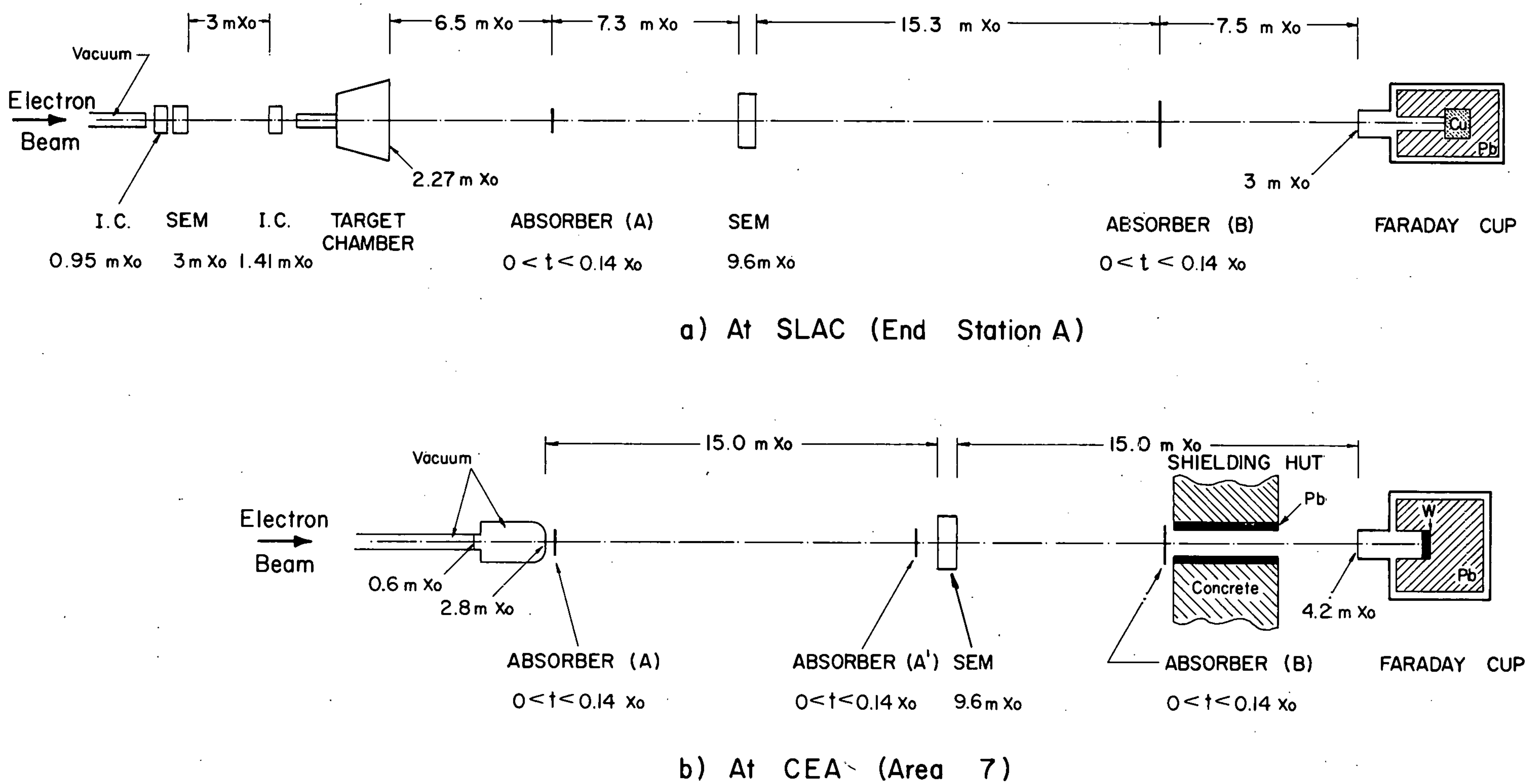

FIG. 3 — EXPERIMENTAL BEAM RUNS

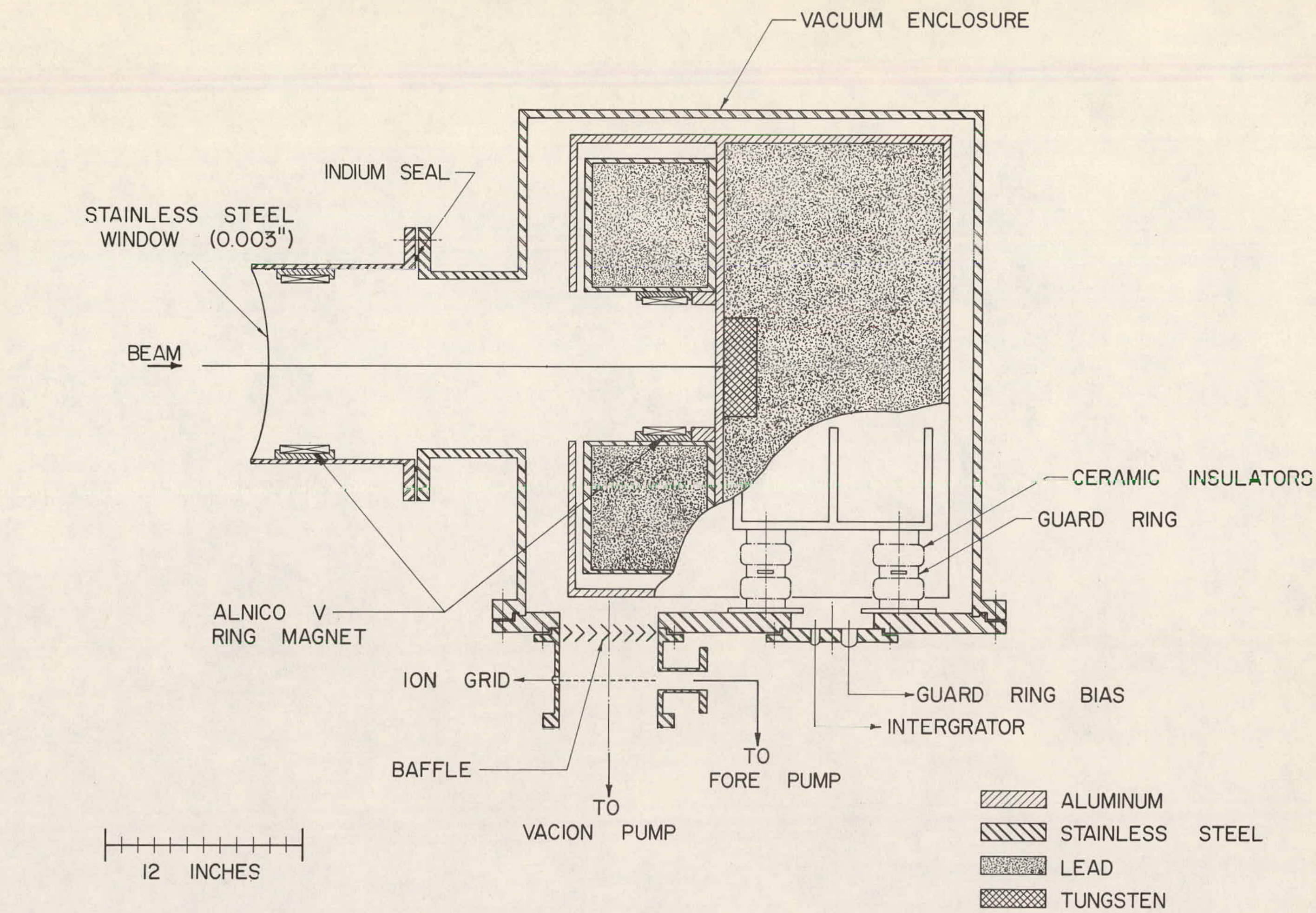

FIG. 4a – CEA FARADAY CUP (No.1)

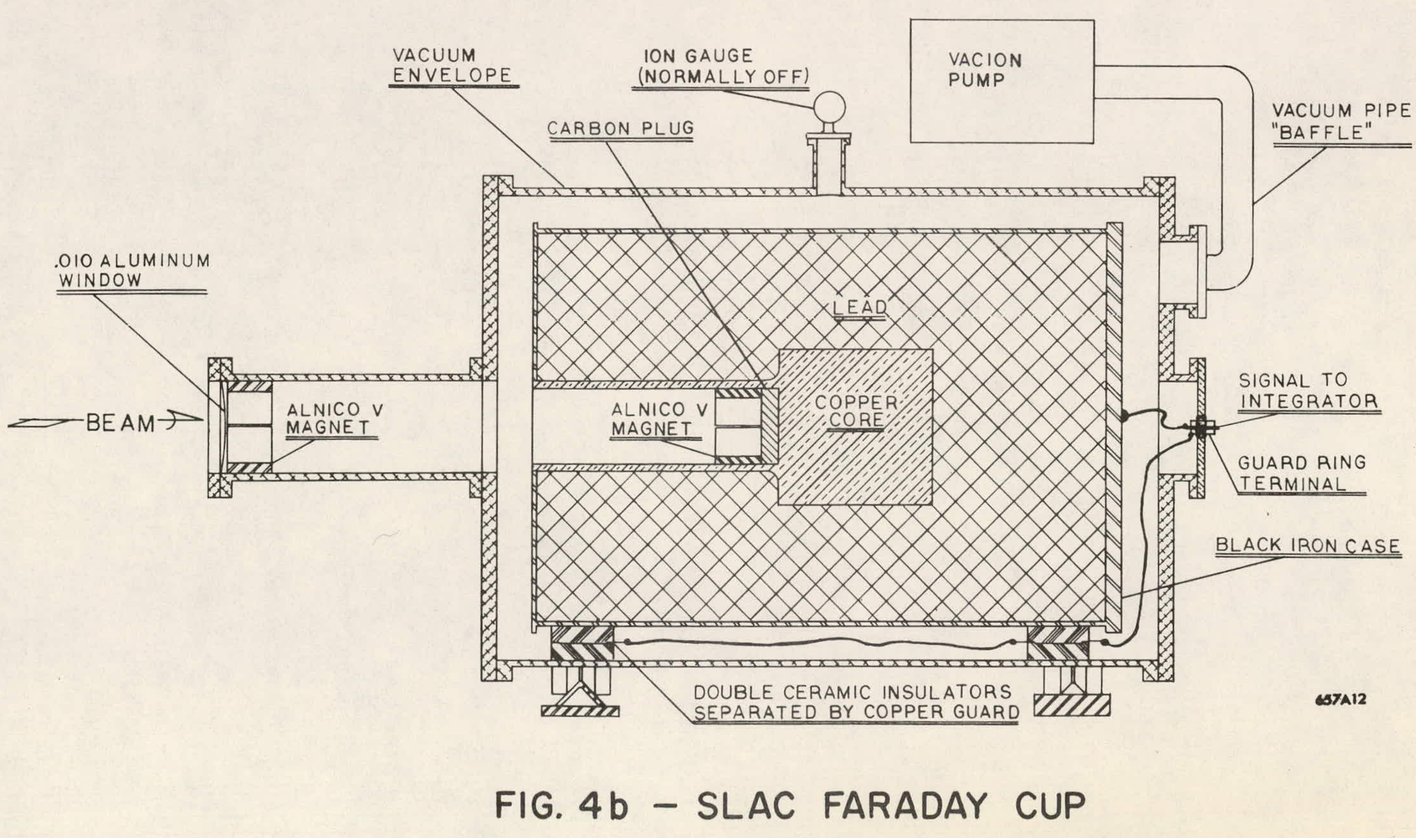

FIG. 4b – SLAC FARADAY CUP

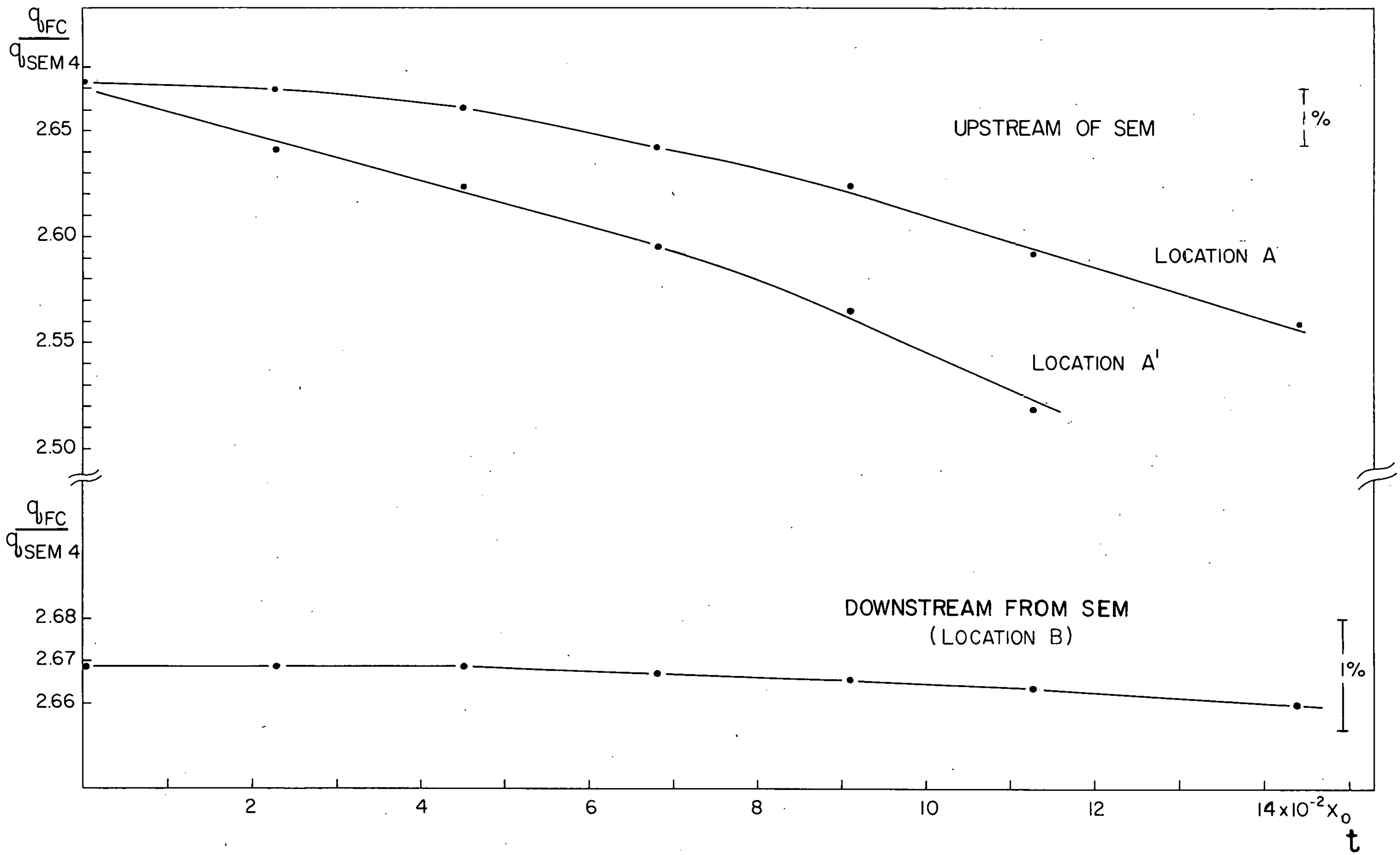

FIG. 5—DEPENDENCE OF MONITOR RESPONSE ON ABSORBER IN THE BEAM (CEA)

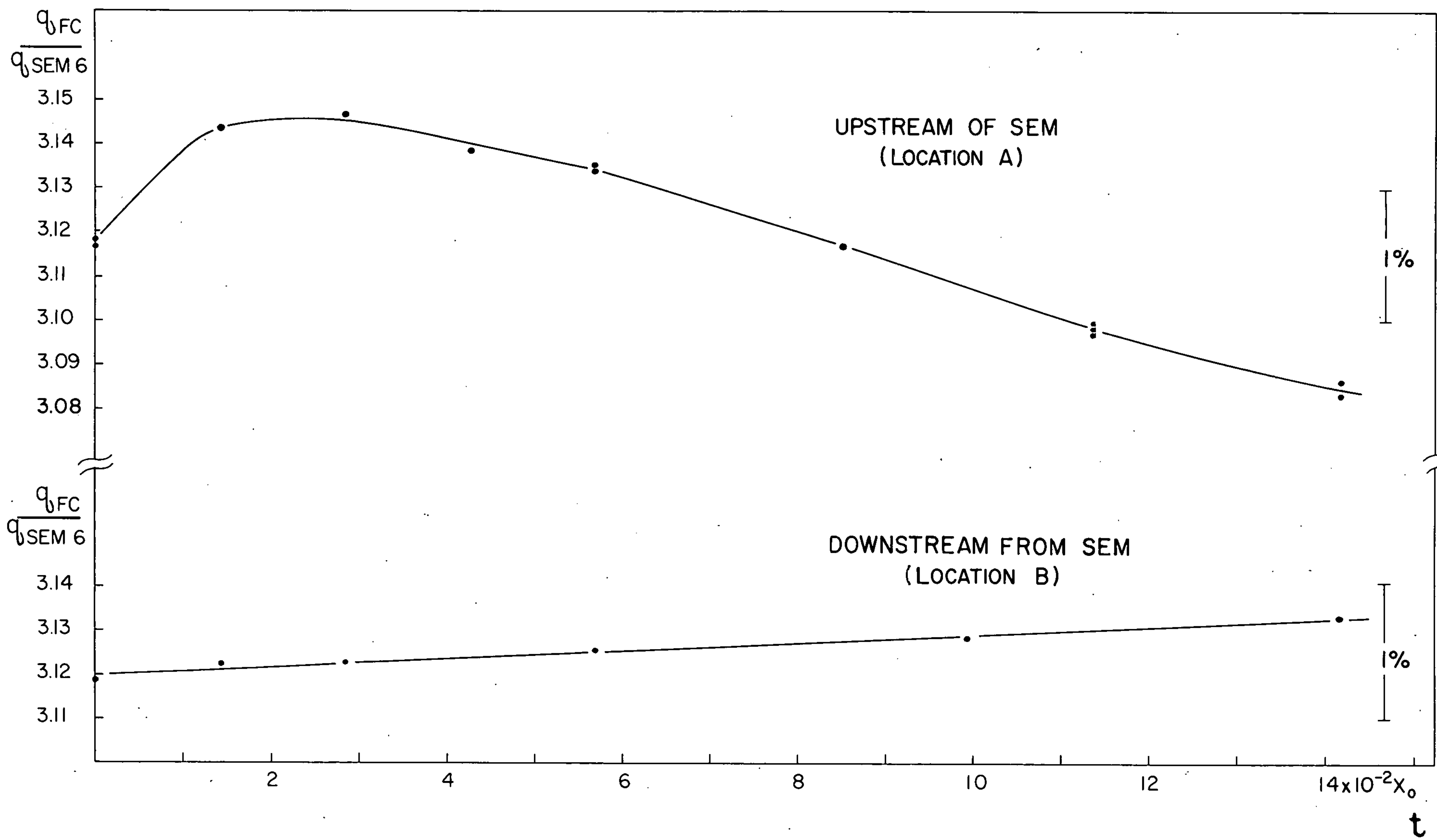

FIG. 6 – DEPENDENCE OF MONITOR RESPONSE ON ABSORBER IN THE BEAM (SLAC)

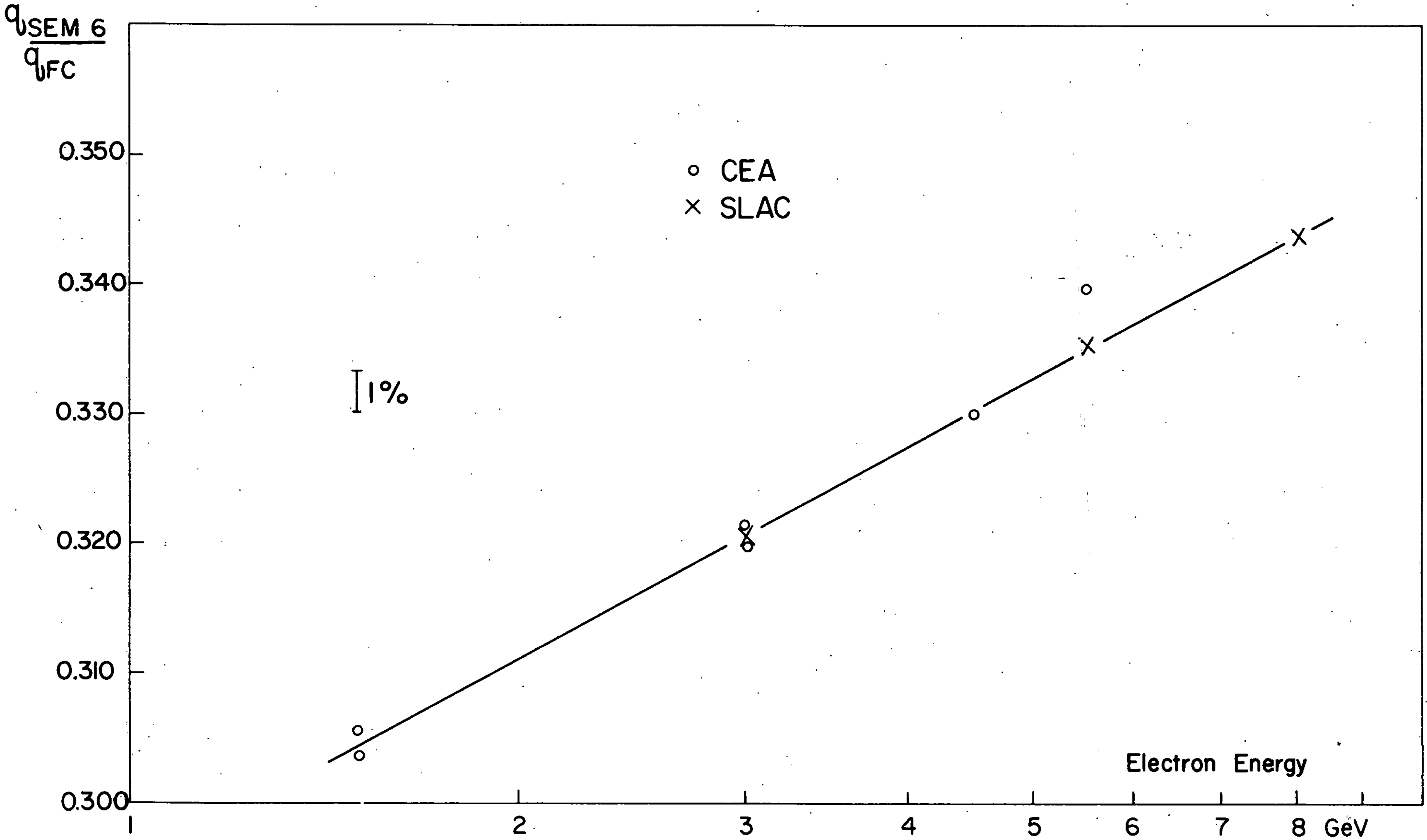

FIG. 7 – SEM 6 RESPONSE AT CEA AND SLAC

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