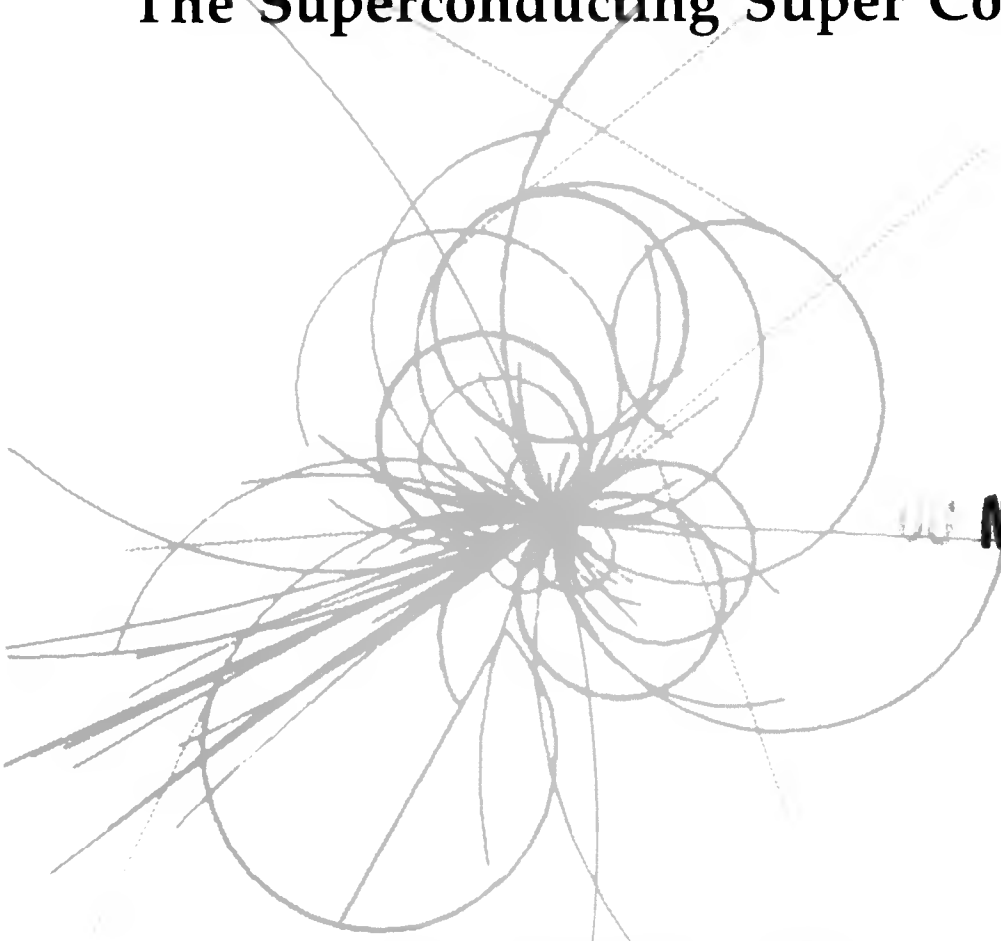
The Superconducting Super Collider



Status of the SSC Photodesorption Experiment

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I. Introduction

The 20 TeV protons of the SSC will emit significant amounts of synchrotron light. This light will desorb gases from the cold beam tube walls of the SSC, giving rise to a density of gas molecules within the cold bore. To predict this density, data have been taken on photodesorption from cold (4.5 K) beam tubes at the VUV electron storage ring at the National Synchrotron Light Source.

II. The Experiment

Photodesorption data have been taken at VUV ring energies of 600 and 744 MeV corresponding to synchrotron light characteristic energies of 251 and 478 eV, respectively. These characteristic energies bracket the SSC characteristic energy of 284 eV. The incident photon density at which data was taken was typically one to five times that of the SSC with a stored current of 70 mA. Due to collimation of the experiment's synchrotron light, a large fraction of low energy photons were excluded from the test beam tube. For example, 78% of 1 eV photons are excluded. Greater fractions are excluded for lesser photon energies.

Figure 1 is a schematic of the experiment. The length of the cold beam tube is 4.1 meters with the detectors, quadrupole mass spectrometers (QMSs), mounted 0.7 meters from the downstream end. This arrangement allows both the

scattered and direct light to desorb molecules in the vicinity of the detectors. The angle of incidence of the direct light at the detectors was 9.3 mr, versus 1.8 mr for the SSC. Figure 2 is a cross section of the experiment's cryostat at the detectors. QMS A views the directly illuminated section of beam tube and QMS B views a section that is not directly illuminated. Each QMS has two data-taking positions: an "in" position in which molecules exiting the beam tube can directly enter the ionizer of the QMS, and an "out" position in which exiting molecules cannot directly enter the ionizer of the QMS. Signals are recorded for both QMSs with light on and off, in both "in" and "out" positions. The signal of interest, the signal corresponding to molecules exiting the beam tube and directly entering a QMS's ionizer (referred to as the direct signal), is assumed to be given by the double subtraction: "In" (light on - light off) - "Out" (light on - light off). This assumption is the major uncertainty in the final results of the experiment. How reasonable this assumption is will be discussed later.

III. The Data

The "in" - "out" signals for H_2, CO, and CO_2, the only molecules for which signals were detected, are presented in Fig. 3 for QMS A as a function of accumulated photon dose. The signals are normalized to 420 mA of VUV ring beam current at 744 MeV. The ionizers of the QMSs measure instantaneous density; however, for convenience, the signals are reported in the pressure in Torr this density would imply at room temperature. Measurements are given for a stainless steel (SS) beam tube and a copper-plated stainless steel (Cu-SS) beam tube. In general, the Cu-SS signals are less than or equal to the SS signals. Figure 3 shows the H_2 signal to be one to two orders of magnitude greater than the CO signal, and the average CO signal to be a factor of seven greater than the average CO_2 signal. Of concern are the large H_2 signals

at high accumulated photon dose, indicating that the H_2 density within the beam tube may be increasing as the dose increases. These high H_2 signals may also be due to a warming and cooling of the cryostat that occurred prior to these measurements. Further data will be taken at high exposures.

Figure 4 presents the ratio of H_2 "in" - "out" signals for QMS B to QMS A as a function of accumulated photon dose. The average of the ratios is slightly greater than one, but is consistent with one given calibration errors. The B to A ratios for CO and CO_2 are also consistent with one.

The number of molecules desorbed per incident photon (η) from room temperature SS and Cu-SS are presented in Figs. 5 and 6, respectively, as a function of accumulated photon dose. The ηs for the two surfaces are nearly equal with the ηs for the Cu-SS surface being slightly less at high doses. It should be noted that the H_2 η is about 2.5 times the CO η. This is to be compared to the cold H_2 signal being one to two orders of magnitude greater than the cold CO signal. On the other hand, warm and cold CO to CO_2 ratios are about equal.

IV. Analysis

The direct signals (as defined in Section II) at the QMSs' ionizers are proportional to the pressures within the test beam tube. The ratio of beam tube pressure to ionizer pressure, which is independent of temperature, was measured in a test device in which a known pressure in a simulated beam tube was compared to ionizer response. The results of this calibration measurement for various gases are presented in Table 1. A Monte Carlo calculation of this ratio gives 78, in agreement with the measured ratios. The factor of 2 variation with test gas is not considered serious, given the accuracy of the measurement and the magnitude of the ratio. To be conservative, the value of 150, corresponding to H_2, is used.

Table I

Ratio of Pressure in Beam Tube to Pressure at Ionizer.

Gas	Ratio
H_2	154
He	103
N_2	95
Kr	72

This factor of 150 is applied to the direct signals at the QMSs' ionizers to obtain the pressure within the experiment's beam tube. As stated at the end of Section II, the direct signal is assumed to be the "in" - "out" signal. To test how reasonable this assumption is, a calculation of the direct signal was made based on the warm ns of Figs. 5 and 6, the energies of desorbed molecules from warm surfaces, the number of bounces desorbed molecules make before sticking to a cold surface, and the fraction of energy retained after each bounce.

Information on the number of H_2 bounces was obtained by moving the edge of the collimated synchrotron light past the detectors, and recording the H_2 signal as a function of distance of the light edge from the detectors. A plot of one of these measurements with an error function fit is presented in Fig. 7. The average error function rms width of these measurements is 8.0 $\pm$ 0.9 cm. When the component due to smearing of the light edge caused by the horizontal width of the VUV ring electron beam is removed, the rms distance along the beam tube that the H_2 signal originates from is 6.3 $\pm$ 1.3 cm. The detectors directly view an rms width of only 0.3 cm. The number of molecule bounces that would produce an rms of 6.3 cm is approximately fifteen. If

scattered light is responsible for some of the rms width, then the number of bounces needed would decrease. A number of bounces greater than thirty, however, would be difficult to reconcile with the measurement.

Figure 8 presents a calculation of the H_2 direct signal as a function of number of bounces, for an η of 0.025, for a beam current at 420 mA at 744 Mev, and for various assumptions of H_2 desorbed energy (EØ) and fractional energy retention (f) after each bounce. It can be seen from Fig. 8 that at fifteen bounces, desorption energies of 0.1 to 1.0 eV, and fractional energy retention factors of 0.5 to 0.9, the calculation gives direct signals compatible with the H_2 "in" - "out" signals of 0.5 to 8.0 x 10^{-10} Torr, as presented in Fig. 3. To convert Fig. 8 to a calculation of CO or CO_2 direct signal would involve only multiplication of each curve by factors of 1.5 and 0.6, respectively. Only a few bounces for either CO or CO_2 are compatible with the "in" - "out" data of Fig. 3. Also, it can be seen that desorption energies corresponding to 4.5 K are improbable for CO and CO_2 due to the enormous signals that would result.

All the above, of course, is based on the assumption that ηs at 4.5 K are equal to ηs at room temperature. This would seem to be a reasonable assumption given that the ratio of incident photon energy to either molecular energy or wall temperature energy is large. The conclusion from the calculation is that for reasonable assumptions, direct signals compatible with the "in" - "out" signals are obtained. Even though this does not prove the case, the "in" - "out" signal is taken to be the direct signal. Table II gives pressures within the experiment's beam tube based on the data of Fig. 3, and the extrapolation factor of 150, for 420 mA of VUV ring beam current at 744 MeV.

Table II

Pressure within Experiment's Beam Tube

Gas	Pressure (Torr)
H_2	0.8 to 12. x 10^{-8}
CO	2.1 x 10^{-10}
CO_2	3.0 x 10^{-11}

To obtain the pressure within the SSC's bore, the pressure in the experiment's beam tube can be extrapolated by either ratio of incident synchrotron light power density, or by ratio of incident synchrotron light photon density. To investigate by which quantity photodesorption scales, consecutive data runs recording the H_2 signal were taken at VUV ring beam energies of 744 and 600 MeV. If photodesorption scales by power density, the ratio of H_2 744 MeV signal to 600 MeV signal would be 2.41; if photodesorption scales by photon density, this ratio would be 1.41. The ratios of the H_2 signals from QMS A and QMS B, respectively, are 1.43 $\pm$ 0.19 and 1.53 $\pm$ 0.27. The errors reported are statistical errors only. Systematic errors, such as possible beam movement in changing VUV ring energy, are not included; however, scaling of photodesorption by photon density is clearly favored and is used to extrapolate to the SSC. Table III presents the pressures within the SSC beam tube for 70 mA of beam current, and also gives the resulting SSC luminosity lifetimes, assuming a proton-nucleon cross section of 50 mb. The shortest lifetime of 43 hours, due to the upper limit of H_2 pressure, does not seriously degrade the SSC's luminosity lifetime of approximately 24 hours due to beam-beam collisions at the interaction points. Thus, gas pressures within the SSC bore due to photodesorption do not present a serious problem for the luminosity lifetime of the SSC. However, the pressures of Table III will give

rise to radiation backgrounds in the SSC tunnel, which will seriously affect electronic component lifetimes. A more accurate determination of H_2 pressure within the SSC bore will help in quantifying this problem.

Table III

Pressure within SSC's Beam Tube and Associated Luminosity Lifetimes.

Gas	Pressure (Torr)	Lifetime (hours)
H_2	0.2 to 3.0 x 10^{-8}	650 to 43
CO	5.0 x 10^{-11}	4600
CO_2	7.0 x 10^{-12}	21000

V. Future Measurements

Whether the H_2 signal is rising with increased light exposure will be investigated in a future long exposure data run. Also, measurements will be made on photodesorption from a cold aluminum beam tube. At present, experiments on photodesorption from a cold aluminum beam tube are being performed at KEK. Also at KEK, the effects of a magnetic field upon photodesorption will be investigated in the near future.

A possible process that has not been sufficiently studied by the present experiment is whether very low energy photons ($\leq$ 0.1 eV) directly desorb molecules that have been cryo-pumped by the cold beam tube walls. As was stated in Section II, low energy photons were largely excluded by the experiment due to collimation. This low energy process, if very efficient, could lead to high pressures, since all desorbed molecules are eventually cryo-pumped. By vertically tilting the experiment's beam tube, only very low energy photons will be admitted, and this possible process can be investigated.

VI. Summary

Photodesorption experiments have been performed on cold stainless steel and cold copper-plated stainless steel. Photodesorption signals for, in order of strength, H_2, CO, and CO_2 have been measured from these cold surfaces. The signals have been extrapolated to predict gas pressures within the cold bore of the SSC. These gas pressures imply luminosity lifetimes that are not a serious problem for the SSC. Future measurements include studies of long exposures, aluminum beam tubes, photodesorption by very low energy photons, and photodesorption in a strong magnetic field.

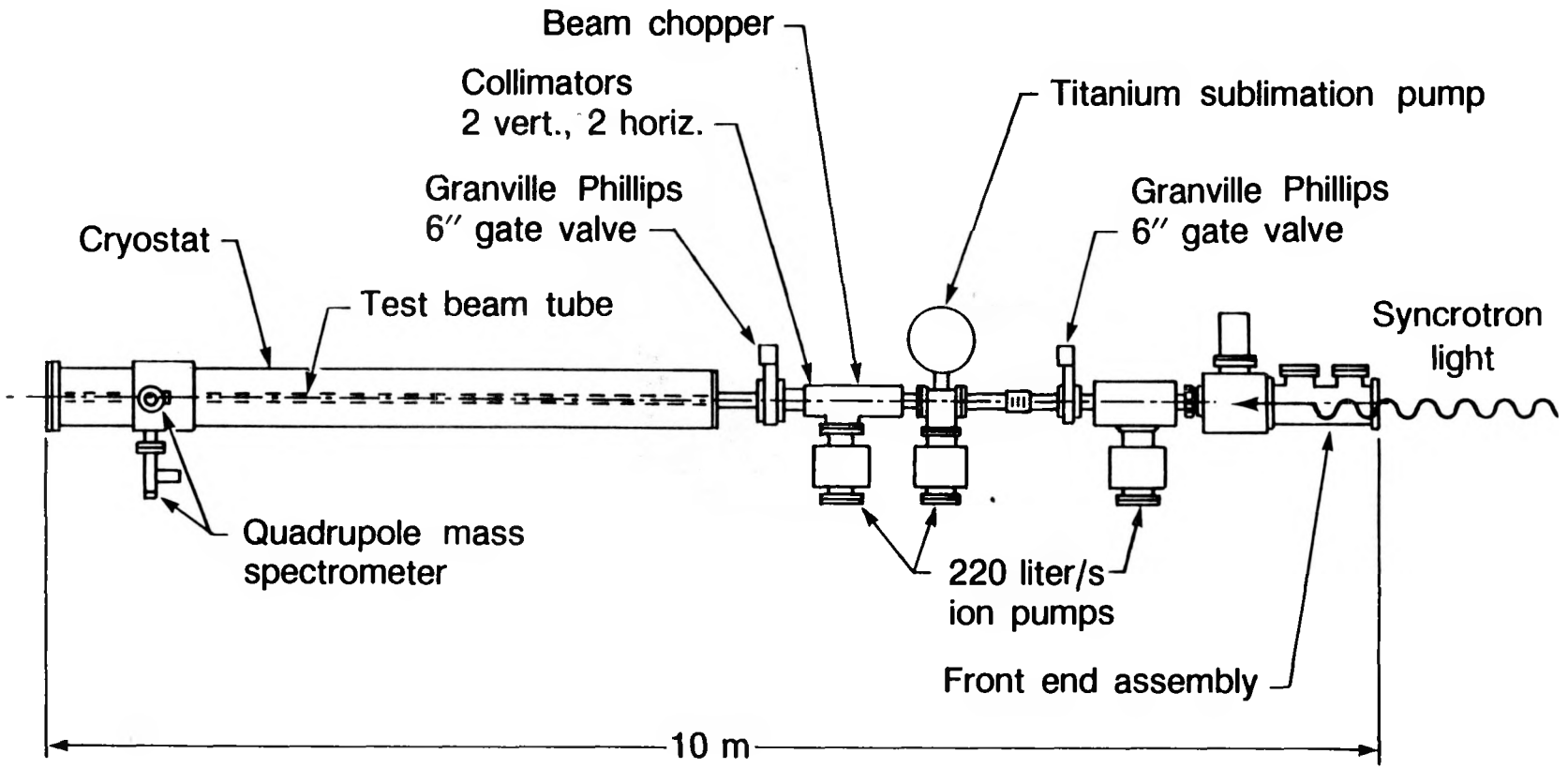

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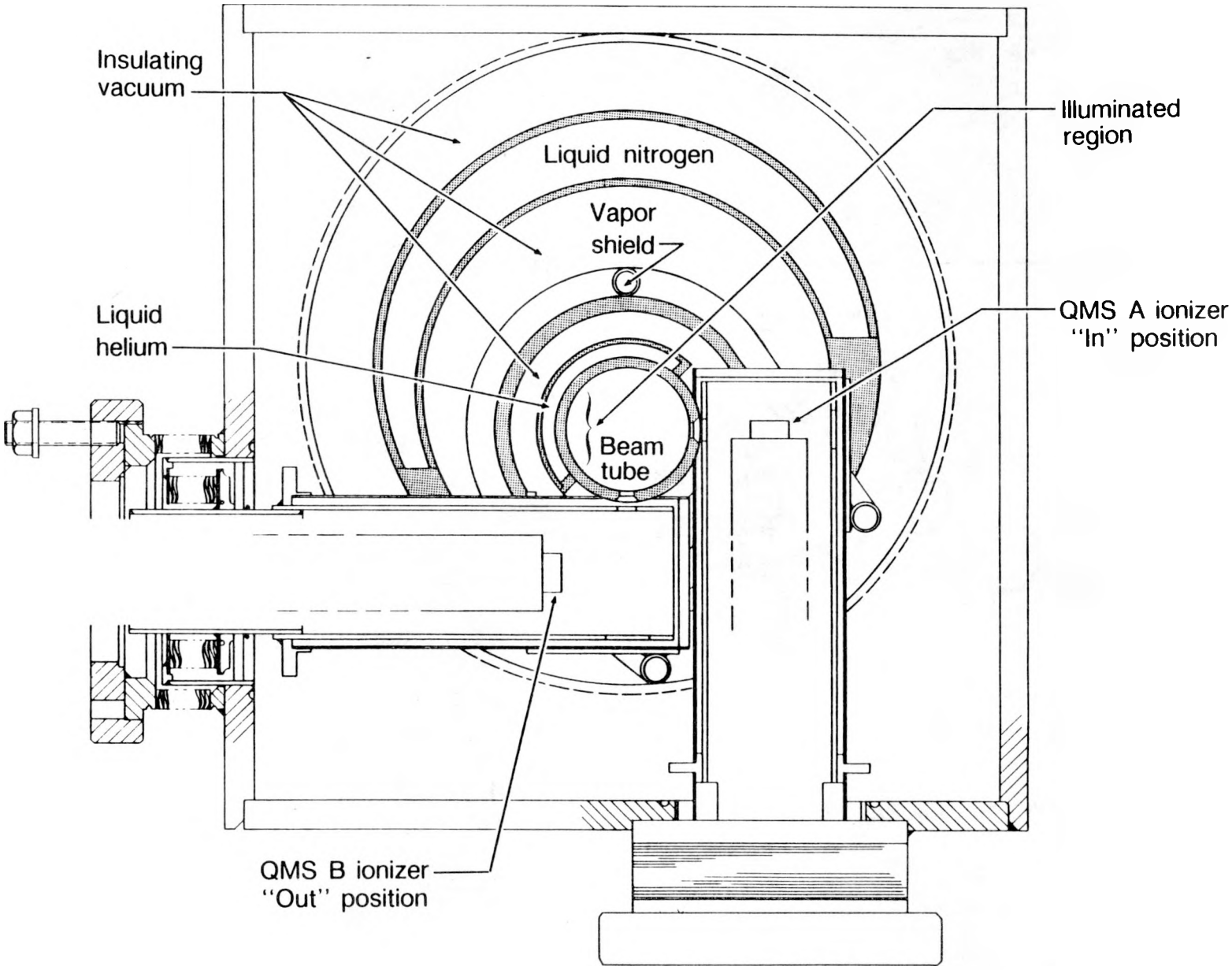
FIG. 1



Cryostat Cross Section at Quadrupole Mass Spectrometers (QMS)

FIG. 2

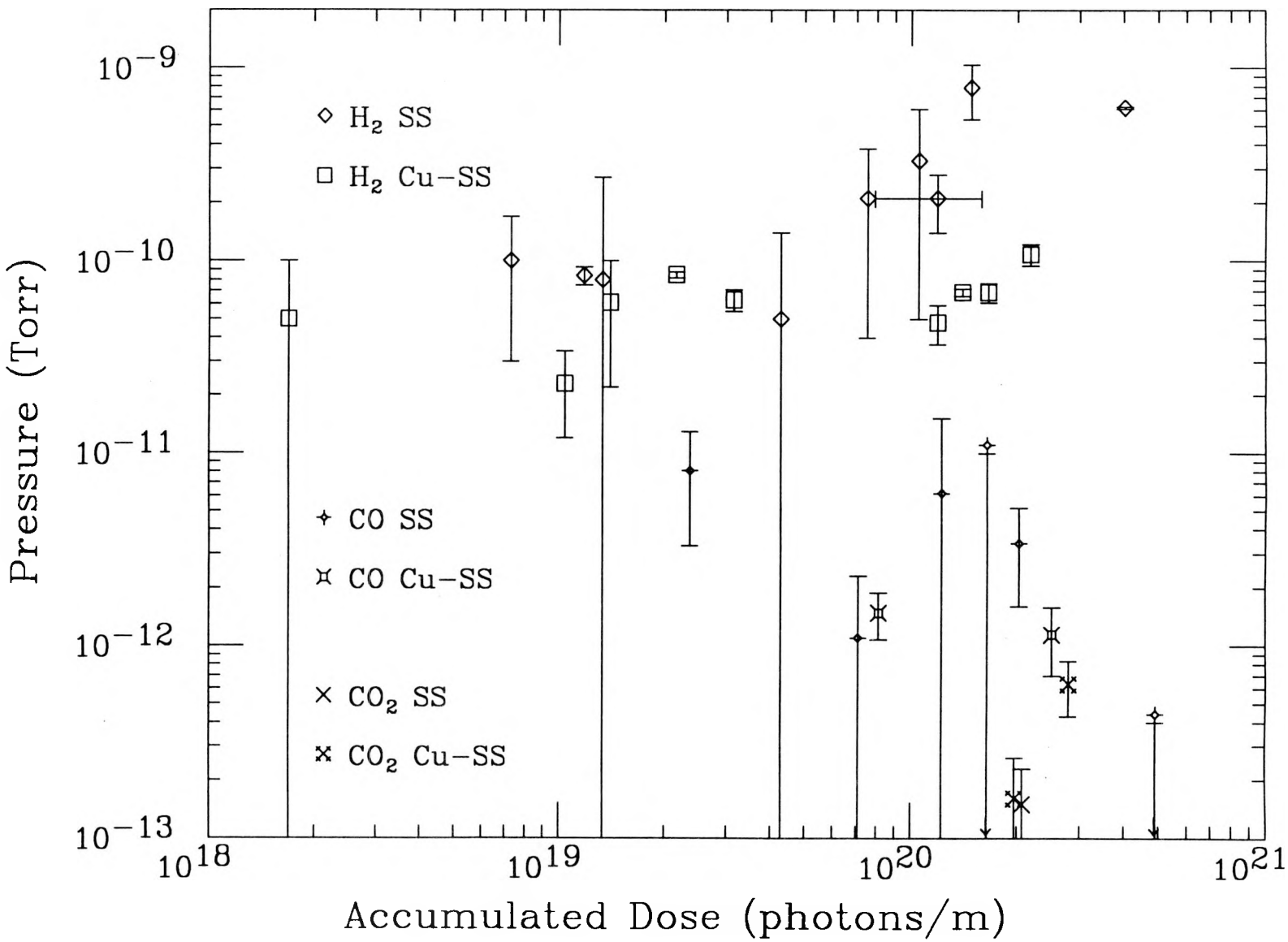

Signals, In−Out Positions
Pressure (Torr)
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
H_2 SS
H_2 Cu−SS
CO SS
CO Cu−SS
CO_2 SS
CO_2 Cu−SS
10^{18}
10^{19}
10^{20}
10^{21}
Accumulated Dose (photons/m)

FIG. 3

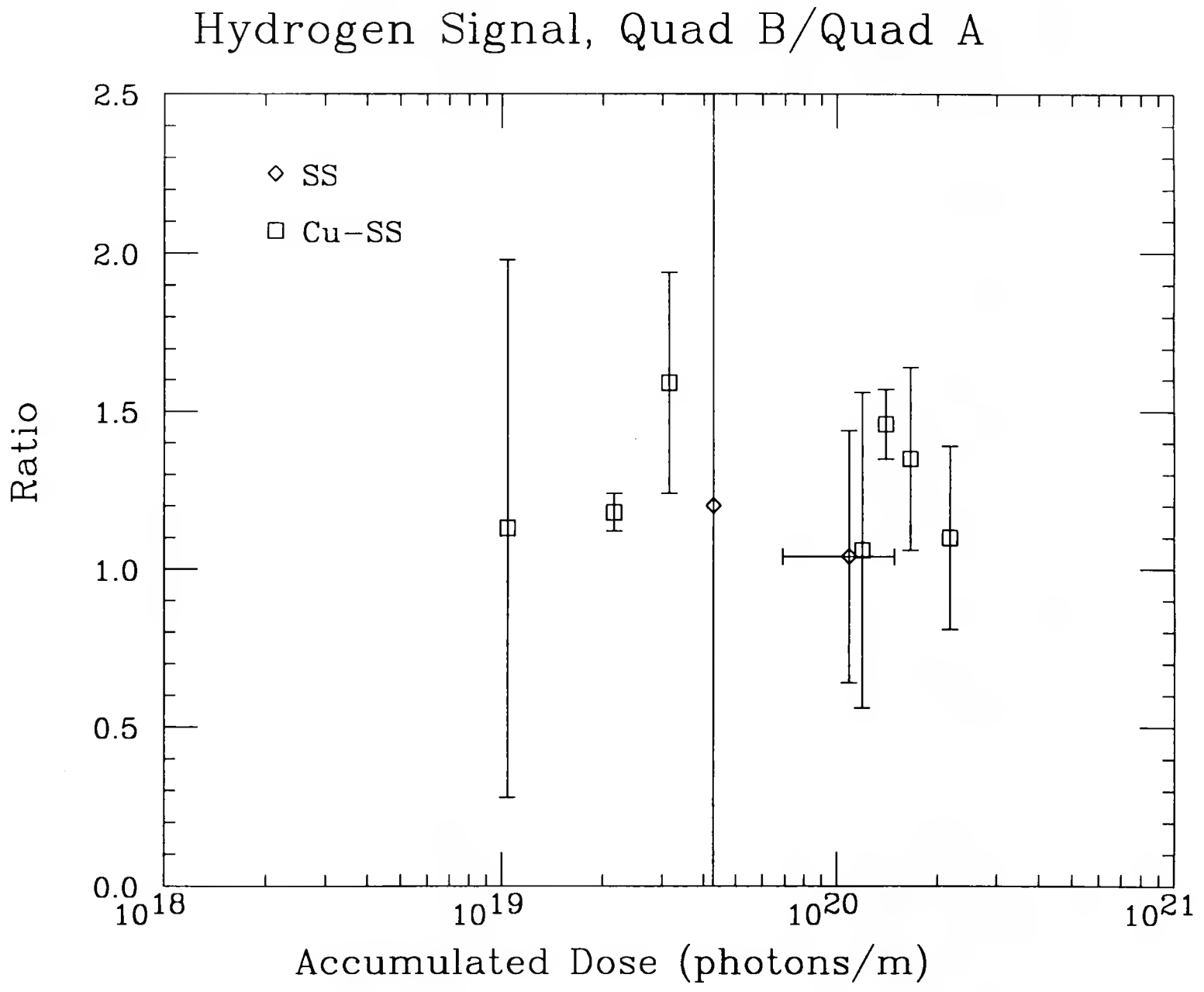

Hydrogen Signal, Quad B/Quad A
SS
Cu-SS
Ratio
2.5
2.0
1.5
1.0
0.5
0.0
10^{18}
10^{19}
10^{20}
10^{21}
Accumulated Dose (photons/m)

FIG. 4

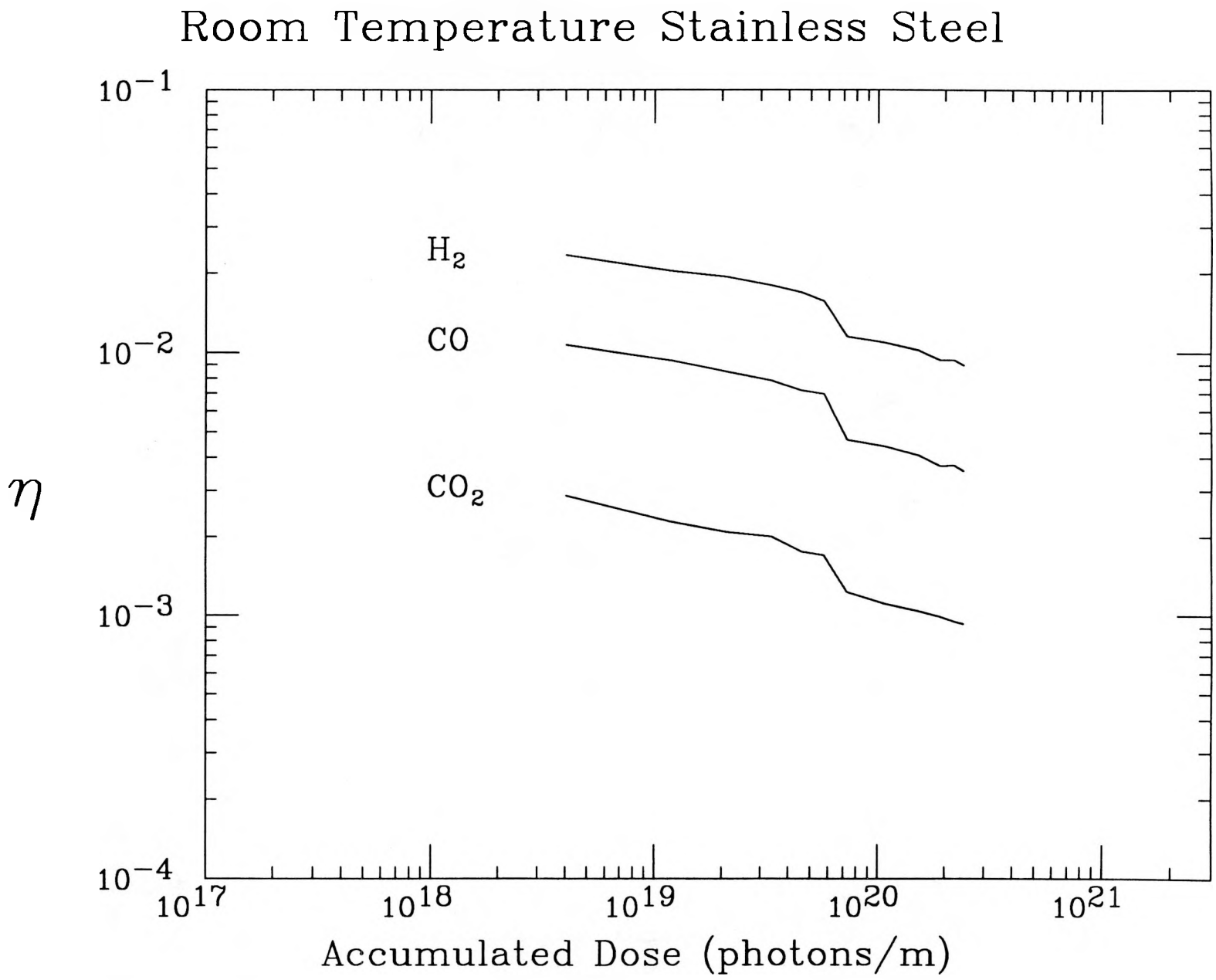

Room Temperature Stainless Steel
10^{-1}
10^{-2}
10^{-3}
10^{-4}
η
H_2
CO
CO_2
10^{17}
10^{18}
10^{19}
10^{20}
10^{21}
Accumulated Dose (photons/m)

FIG. 5

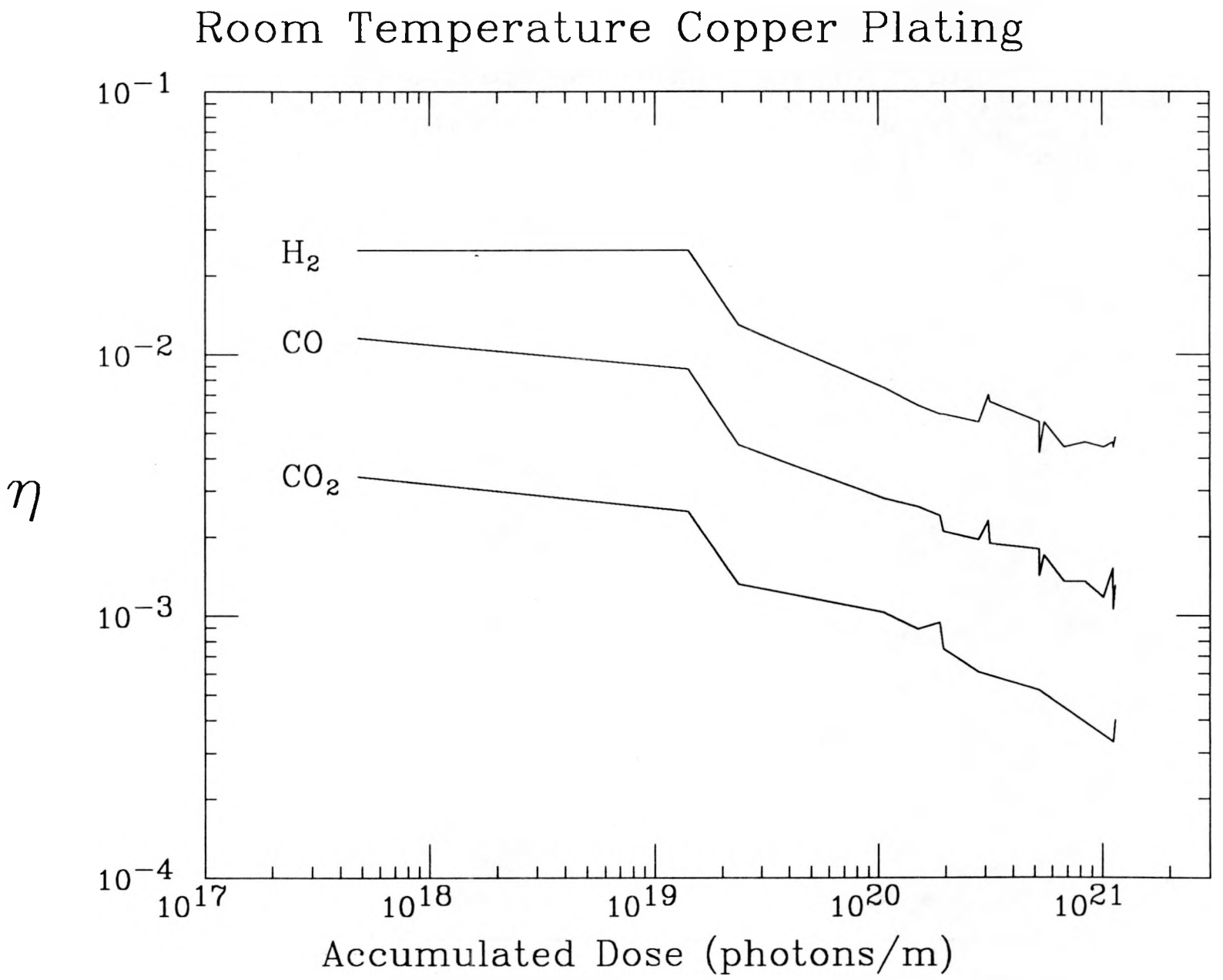

Room Temperature Copper Plating
10^{-1}
10^{-2}
10^{-3}
10^{-4}
η
H_2
CO
CO_2
10^{17}
10^{18}
10^{19}
10^{20}
10^{21}
Accumulated Dose (photons/m)

FIG. 6

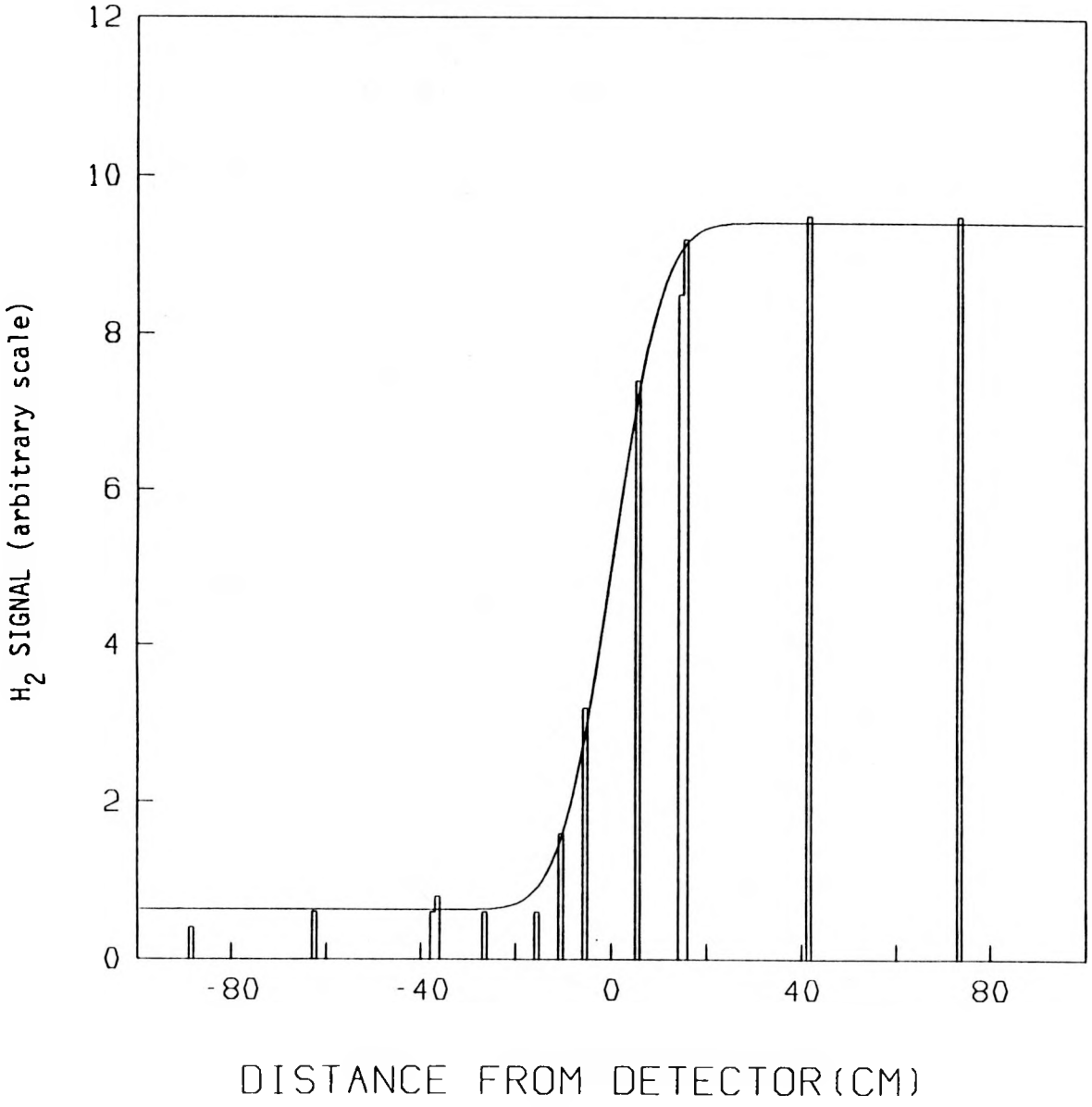

12
10
8
6
4
2
0
H_2 SIGNAL (arbitrary scale)
-80
-40
0
40
80
DISTANCE FROM DETECTOR(CM)

FIG. 7

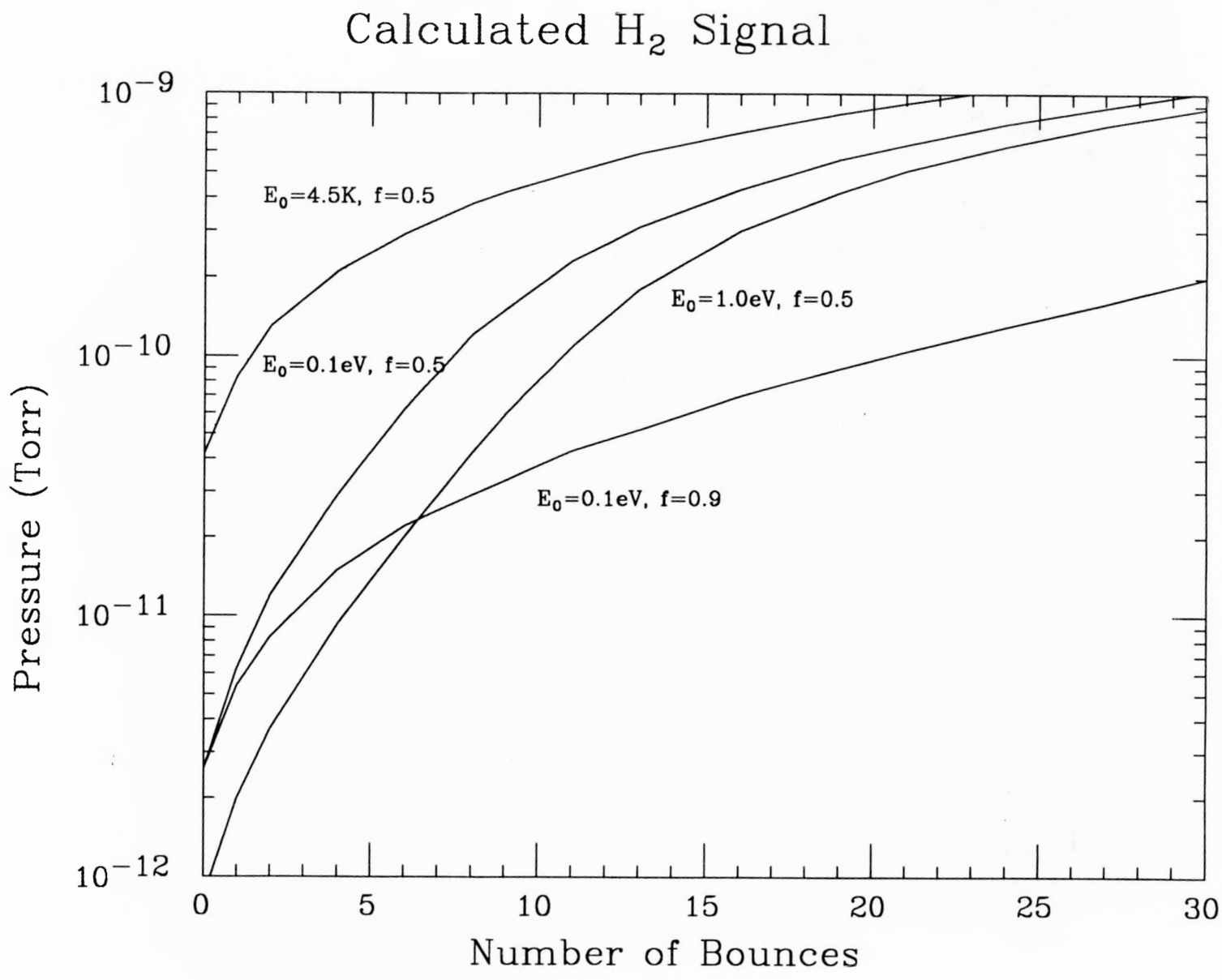

Calculated H_2 Signal
Pressure (Torr)
10^{-9}
10^{-10}
10^{-11}
10^{-12}
E_0=4.5K, f=0.5
E_0=0.1eV, f=0.5
E_0=1.0eV, f=0.5
E_0=0.1eV, f=0.9
0
5
10
15
20
25
30
Number of Bounces

FIG. 8