PS/ML/Note 84-8
24.4.1984

SYNCHROTRON RADIATION INDUCED DESORPTION OF A PS VACUUM CHAMBER:RESULTS OF TESTS AT DCI-ORSAY....

1)Introduction and summary:

In some recent notes, the specific synchrotron radiation induced pressure rise of the PS when used as LEP injector has been extrapolated (ref.1,2) and measured using an X-ray source (3).
Since none of these approaches could be entirely entrusted to give exact figures,a 3 meter long,unbaked,Fluginox 130 (*) PS vacuum chamber cleaned by standard UHV perchlorethylene + alcaline treatment has been exposed to synchrotron light,using the LEP vacuum group test facility at DCI Orsay (4).
At the PS 3.5 Gev/c synchrotron radiation spectrum (critical energy 1.4 kev) and angle of incidence (45 mrad),the absolute specific pressure rise has been found to be,in DC mode,5.10^{-7} Torr/mA initially down to 5.10^{-8} Torr/mA after 43 mAh of PS equivalent beam dose.These values are roughly two times lower than the ones previously extrapolated (2),and 50% larger than those measured with X-rays (3).
In order of importance the gases desorbed were CO_2 (45%),CO (34%),H_2 (17%),CH_4 (4%) with practically no H_2O.Attempts to pulse the DCI beam light with a shutter were only marginally successful,in the sense that it only confirmed semi-quantitatively the guessed 2) dynamic pressure behaviour of the PS running in pulsed mode;the absolute pressure rise was found to scale with the duty factor and the pressure modulation is smoothed out due to both high pumping system time constant and delayed desorption.

2)Installation at DCI (see figure 1):

The DCI test set-up has been described elsewhere 4).The 3 meter long PS vacuum chamber was installed at 45 mrad glancing angle from the 5 mrad collimated synchrotron light beam,giving thus approximately 0.7 meter of directly exposed surface,roughly centered in the chamber.A ferrite PS beam stopper used as a shutter was installed in sandwich between the test set-up and the chamber.The shutter was pneumatically operated with a double acting cylinder,remotely controlled by a timer allowing separate setting of cycle time and time open from the control room.

(*)Fluginox 130(TM):Ni 26%,Cr 15%,Ti 1.8%,Mo 1.2%+V+Bore

The chamber was itself equipped with a saturated PS 200 l/s ion pump,not powered,to be used as an eventual source of contaminant during a subsequent regenerating bake-out,prior to the second series of measurements.In addition,the chamber had at each of its extremities a Bayard-Alpert ion gauge (P1 and P2,see figure 1),permanently connected to a chart recorder.A week prior to the first test,the system was evacuated by means of the test set-up ion and titanium sublimation pumps,down to 5.6 10^{-8} Torr base pressure at the time of the first series of measurements,and with a typical residual gas spectrum for an unbaked system ,after a week of pumping (see figure 3).

3)First series of measurements (22.2.1984):

The energy of the DCI electron storage ring was set at 1.32 Gev/c,value at which the photon spectrum of the synchrotron light matches that of the PS at 3.5 Gev/c (Ec=1.4 kev,see reference 1).During the run the PS chamber was exposed to a total dose of 1 Ah,with three different stacks of beams:first with initial intensity of 20 mA (equivalent to 0.9 mA in the PS,see ref.1),then 60 mA (2.5 mA in the PS),and finally 120 mA (5 mA nominal in the PS).
The run was shared between periods with shutter open (DC mode) and shutter running with a duty factor (Time open divided by cycle Time) of 0.4 (0.6 seconds OPEN,1.5 sec CYCLE TIME).One test with a duty factor of 0.8 was also made.
Finally the last two hours of the session were used to explore the variation of the specific pressure rise with beam energy,between 1.1 Gev/c (Ec=0.8 kev) and 1.6 Gev/c (Ec=2.5 kev).

Figure 2 gives an overall account of the specific gauge pressure rise as a function of beam dose for the complete session,as measured by the test set up gauge PO.

3.1.Results in DC mode (shutter open):

Figure 4 shows the evolution of the absolute partial pressures in the test set up as a function of time.Troughout the period of observation CO_2 remained the dominant residual component,followed by CO.One can observe that the usual smoothness and continuity in the decrease of partial pressures with dose cleaning do not exist,as these curves contain portions measured with shutter open,shutter closed,and shutter pulsing.It is seen in particular that with shutter closed or pulsing,the amount of outgassing is systematically higher than with shutter open.Referring to figure 1 showing the test set up,it is obvious that the RGA and gauge PO being placed upstream of the test chamber plus shutter,these devices cannot differentiate between the synchrotron light's induced outgassing coming from the chamber (shutter open),or the shutter itself and its direct surroundings (shutter closed).
It is not clear why the amount of overall outgassing should be higher when the shutter is pulsing (effect of some back-scattered photo electrons onto the gauge P ?,some gauge electrometer integration effect ?)

nor can it be assessed on the relative cleaning rate in pulsed or DC mode.

3.2.Results in pulsed mode:

The dynamic behaviour of the test chamber in pulsed mode can be obtained differentially from the recording of the P1 and P2 pressures downstream of the shutter,provided that the gauge signals can be trusted to be coming from the residual gas molecules and not from photon produced or collected photo electrons (figure 5).Tests of signals recorded by the gauges P1 and P2 with hot filaments turned off have shown that only gauge P2 was influenced by incoming or reflected photons,giving an equivalent pressure signal of 1.5 10^{-7} Torr per 60 mA in DCI.The gauge signal was of the same sign as the one due to the gas (ions),and could be due to photo electrons created on the gauge collector.The dotted curve for P2 on figure 5 incorporates this correction,on the assumption that this parasitic signal onto gauge P2 is proportional to the beam current in DCI.Although probably very likely so,this proportionality has not been checked experimentaly,and the following discussion should be taken with this reserve.

On the basis of the P1 and P2 pressure recordings in pulsed mode (see figures 1,5,6),one can make the following observations:

a) As the chamber linear outgassing is proportional to P2-P1 via the formula:

$$(1) \quad Q\ (Tls^{-1}m^{-1}) = 2\ C\ (P2-P1)/\ L^2$$

with C being the specific conductance (C=100 lms^{-1}),L the length and with uniform outgassing,one can see from figure 5 that it scales roughly with the pulsing duty factor when using the average pressure values.

b) The overall system time constant taking into account pumping speed,conductance,volume,instantaneous and delayed desorption is such that in pulsed mode with a duty factor of 0.4 the maximum pressure crest (that the beam will see) represents about 60% of the pressure in DC mode

c) The pressure modulation from crest to crest over a pulse cycle is about 50% of the average value for a duty cycle of 0.4,or in other words the ratio of maximum to minimum pressure is 1.7,taking the P1 pressure line as reference.

Remark:

It is to be noted at this point that these results (b & c) roughly confirm the rather arbitrary dynamic model exposed in reference 2.In particular it certainly places the specific desorption time constant upon removal of the beam in the same range as the physical pumping system time constant.

d) Qualitative observations indicate that delayed desorption and system time constants are such that the pressure stays high for seconds (roughly a factor of 2 down from maximum in 3 to 4 seconds),minutes (a factor of 3 to 4 in 10 minutes),and hours (the base pressure of the system was still 1.5 higher than initial half an hour later),upon removal of the beam.

3.3.Cleaning rate:pulsed mode versus DC mode:

Figure 6 shows a recording of pressures P1 and P2 both in pulsed and DC mode over a period of 10 hours.
From this data,the specific pressure rise for the PS as function of beam dose uncorrected for duty factor has been calculated for a number of points (A to H) from formula (1),taking into account a linear pumping speed of 15 $lsec^{-1}$,and the current scaling factor of 23.6 between DCI and the PS (see reference 1).The result is shown on figure 7.
The agreement between this P2-P1 measurement of $\Delta P/I$ in DCI and the one obtained from the test set up gauge PO in DC mode is astonishingly good,given the uncertainties of the experiment:

If one calculates the gas load from the gradient P2-P1 assuming that it is concentrated in the middle of the test chamber:

$$Q = C * (P2-P1)$$

(with C=66.7 l/sec for 1.5 meter of PS chamber)
and the pressure rise that it implies on the test system gauge PO given a 60 l/sec pumping speed (*),one obtains the following agreement:

	DCI $\Delta P/I$ from P2-P1		DCI $\Delta P/I$ from PO
point A:	$6.6\ 10^{-9}$	Torr/mA	$6.5\ 10^{-9}$
" B:	4.3 "	"	5 "
" E:	3 "	"	5.5 "
" F:	3 "	"	4.2 "
" G:	3 "	"	3 "
" H:	1.8 "	"	2 "
(crosses on figure 1)			(dots on figure 1)

The only discrepancy is for points E&F,for which the remanent gas load from the shutter and its surroundings can only be seen by the test set up gauge PO.

A look at the instantaneous differential cleaning rate $dn/n*dt$ ($n=\Delta P/I$,slopes of curves II and III of figure 7) wether in pulsed or DC mode seems to indicate that there are the same.This would then mean that the chamber cleans as efficiently due to delayed desorption between as during the pulses for the cycle applied (0.6 sec open/1.5 sec),and that the relative number of photons wether in pulsed or DC mode has no influence.This could be the case if desorption is non linear with photon flux,as for instance in models where gas diffusion from the bulk to the desorption layers has to play a role to explain the observed phenomena.However one can probably say that the precision of the measurement is not precise enough to see a difference in cleaning rate,but the chamber nevertheless cleans between the pulses.
Curve III´would be the specific pressure roughly one second after e^+e^- ejection.Protons injected 2 to 3 seconds later in interlaced mode would see a specific pressure increase as indicated on curve V (extrapolated from figure 5).

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* 60 l/sec is the pumping speed of the system as the titanium sublimation pumps were probably saturated (pressure in the 10^{-9} Torr range upward of the C2 conductance)

4)Specific pressure rise as a function of energy:

Figure 8 shows the specific pressure rise (related to DCI beam current) as a function of energy,recorded in the last two hours of the experiment,that is after about 1 Ah of beam cleaning. The pressure rise is seen to increase more than proportionally with energy,above about 1.3 Gev/c.This trend has already been observed when the average photon molecular desorption yield increases with energy [5]),since the number of photons per mA of DCI beam is proportional to energy.The measurement also suggests that the pressure will grow more or less linearly with energy during the acceleration of the e^+ e^- up to 3.5 Gev/c.

5)Second series of measurements (2.3.1984):

In order to reveal any eventual recontamination effect of the chamber surface due to the release of pumped gases in the PS,the specific pressure rise has been checked again a week later than the first measurement after a standard bake-out of the inactive saturated 200 l/sec ion pump (figure 1).During the bake-out of the ion pump,the chamber was pumped with the test system roughing station.The pressure in the chamber normally peaked to 10^{-4} Torr,as usual during similar regenerative procedures in the PS,following an opening to air.After bake-out,activation of the ion and sublimation pumps allowed the pressure in the chamber to go down to the usual 2.10^{-8} Torr with a normal gas spectrum for an unbaked system.
During the following tests with the beam,the shutter was left open and the specific pressure rise as a function of beam energy was recorded.Curve IV on figure 7 gives the evolution of the pressure rise related to PS beam intensity as obtained from the recording of the P1 and P2 pressures.Although some minor superficial recontamination is apparent (see also figure 2),the initial cleaning rate appears to be much faster than on the virgin chamber.

6)Photon induced molecular yield:

Knowing the specific pressure rise,the number of photons per second entering the test chamber,and the relative pumping speed for the different gases,one can derive [4]) the number of molecules produced per incident photon as a function of dose.This is shown on figure 9,where one can see that H2 eventually becomes the most produced gas as cleaning procedes,while being the most easily pumped.

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Experimenters:

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F.Souchet (DCI)

References:

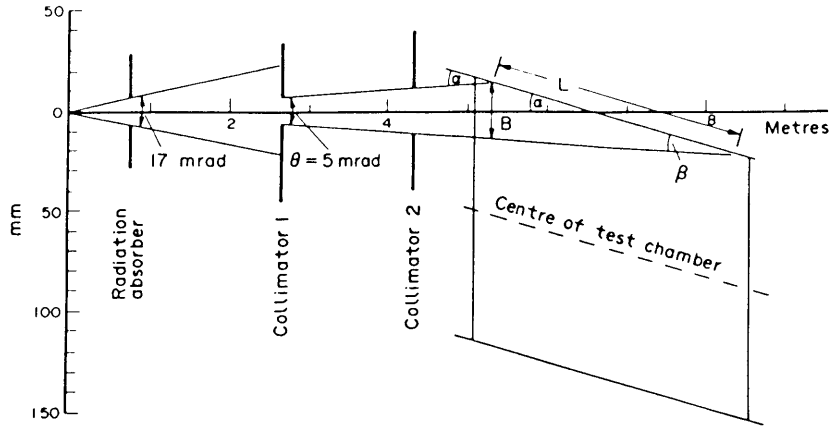
1. Scaling
of the specific pressure rise from the DCI test chamber,
ISR-VA/OG/sm/tn-4 November 1982

2. Consequences for the PS vacuum of the acceleration of e^+e^- for LEP filling PS/ML/Note 82-10 November 1982

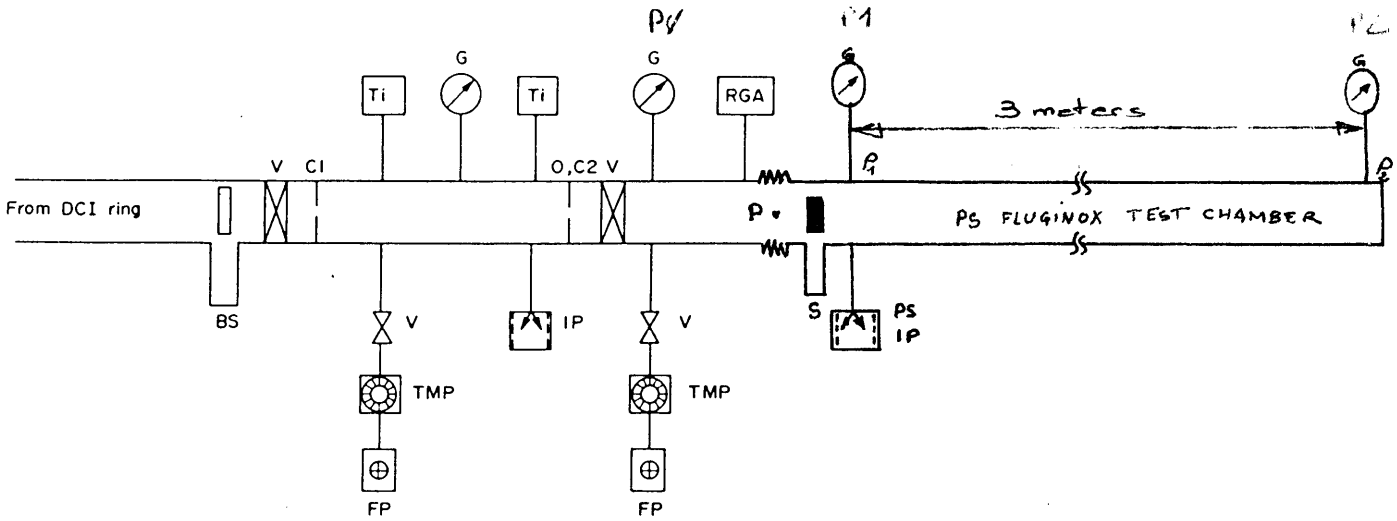
3. X-ray induced desorption measurements on PS components,
LEP/VA/nh November 1983

4. Studies of photon induced gas desorption using synchrotron radiation O.Gröbner &al VACUUM/volume 33/number 7/p.397 to 406 1983

5. LEP VA/AM/sm 10 february 1984. E.Alge & al



The position of the collimators and test chamber with respect to the source point of the synchrotron radiation. The angle of incidence $\alpha = 45$ mrad, β and $\gamma = \alpha \pm \theta/2$ and $\theta = 5$ mrad. The exposed length of the chamber $L = B/\beta \cong .7$ m.



The layout of the vacuum system and test chamber. BS—beam stopper, V—uhv straight through valve, C_1—collimator, C_2—collimator and O—orifice (25 × 25 mm), B—bellows, P—pivot, G—vacuum gauge, RGA—residual gas analyser, Ti—titanium sublimation pump, IP—ion pump, TMP—turbomolecular pump, FP—fore pump. PS-IP: inactive saturated 800 ℓ/s PS ion pump.
S : shutter
P_1, P_2 : ion gauge indication of upstream and downstream pressures

Fig. 1 Test set up and geometry

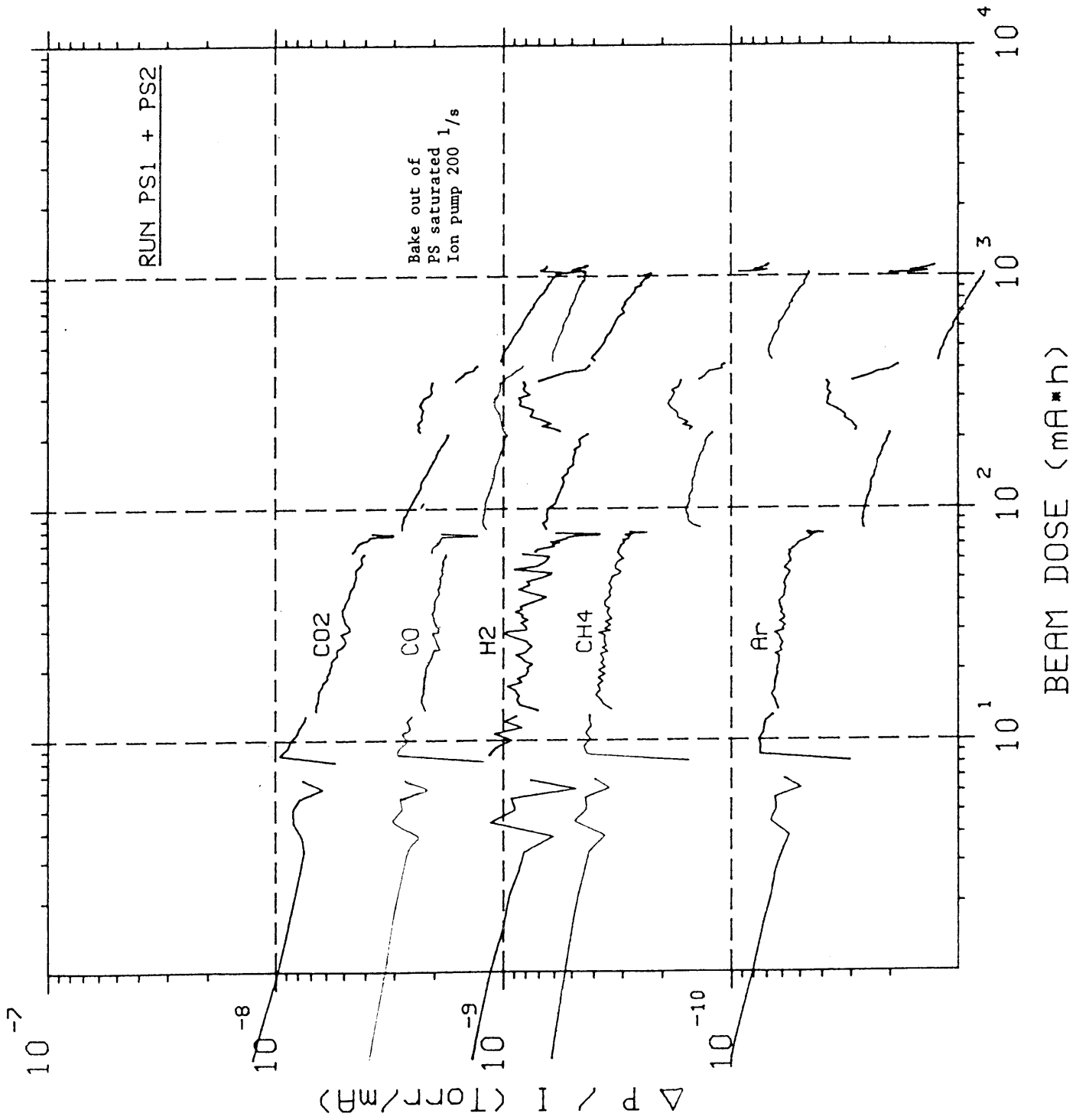
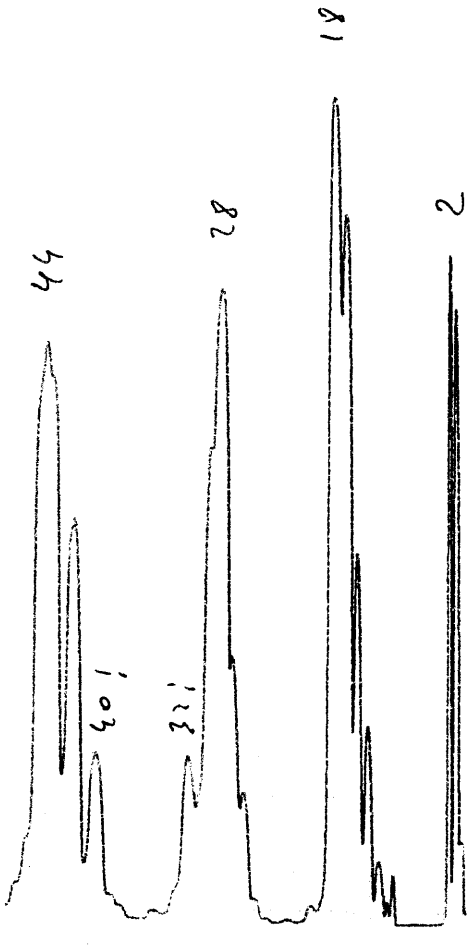

RUN PS1 + PS2
Bake out of
PS saturated
Ion pump 200 1/s
CO2
CO
H2
CH4
Ar
Δ p / I (Torr/mA)
BEAM DOSE (mA*h)
10^-7
10^-8
10^-9
10^-10
10^1
10^2
10^3
10^4

Fig. 2

Start of Test

$P_G = 5.6 \times 10^{-8}$ Torr

SEM 1500 volts



End of Test

$P_G = 8.10^{-8}$ Torr

(same RGA settings)

Fig. 3 Residual gas spectra

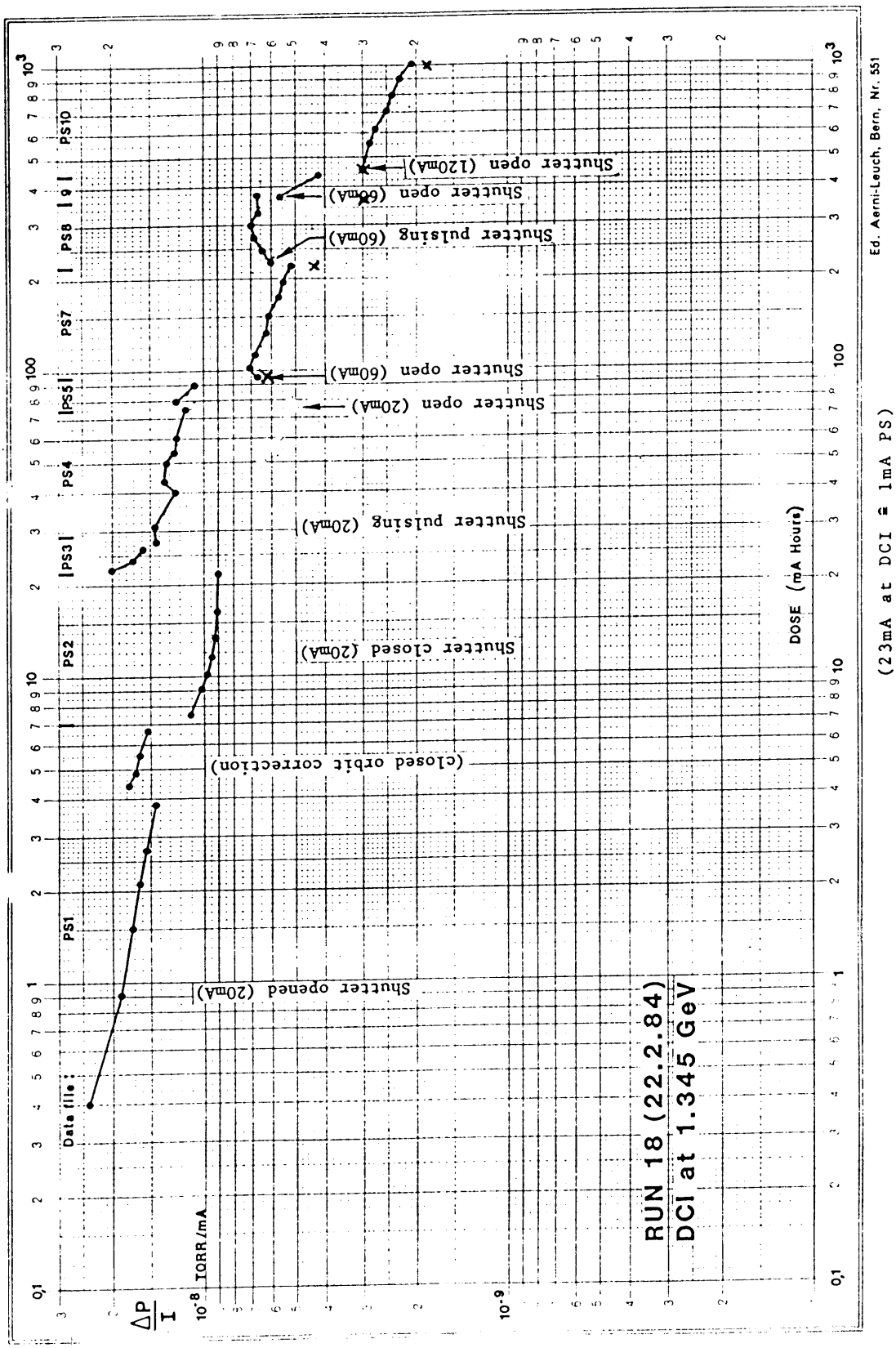


Fig. 4 Absolute pressure rise VS dose

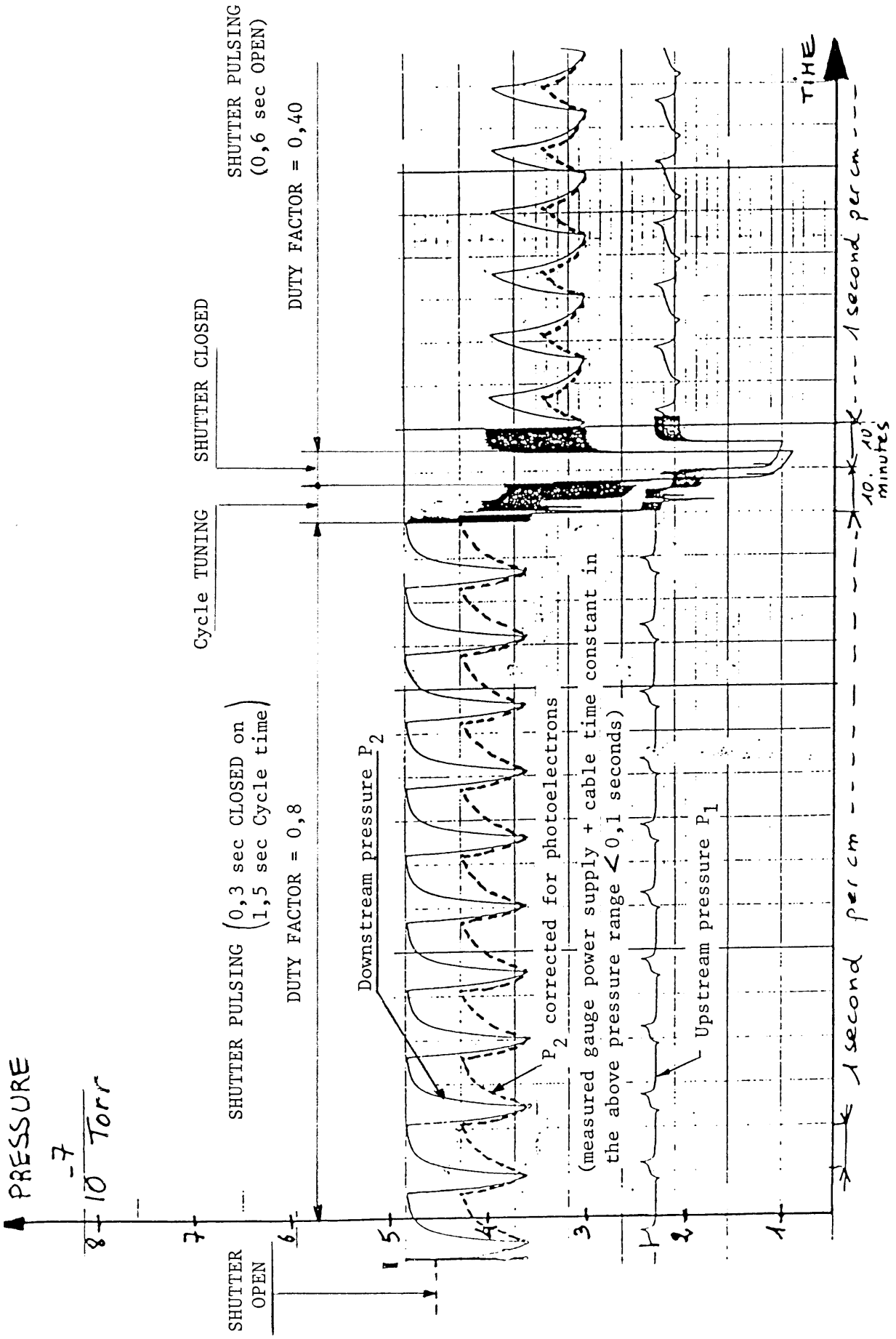


Fig. 5 DYNAMIC PRESSURE BEHAVIOUR OF THE PS VACUUM CHAMBER IN PULSED MODE (20 mA in DCI)

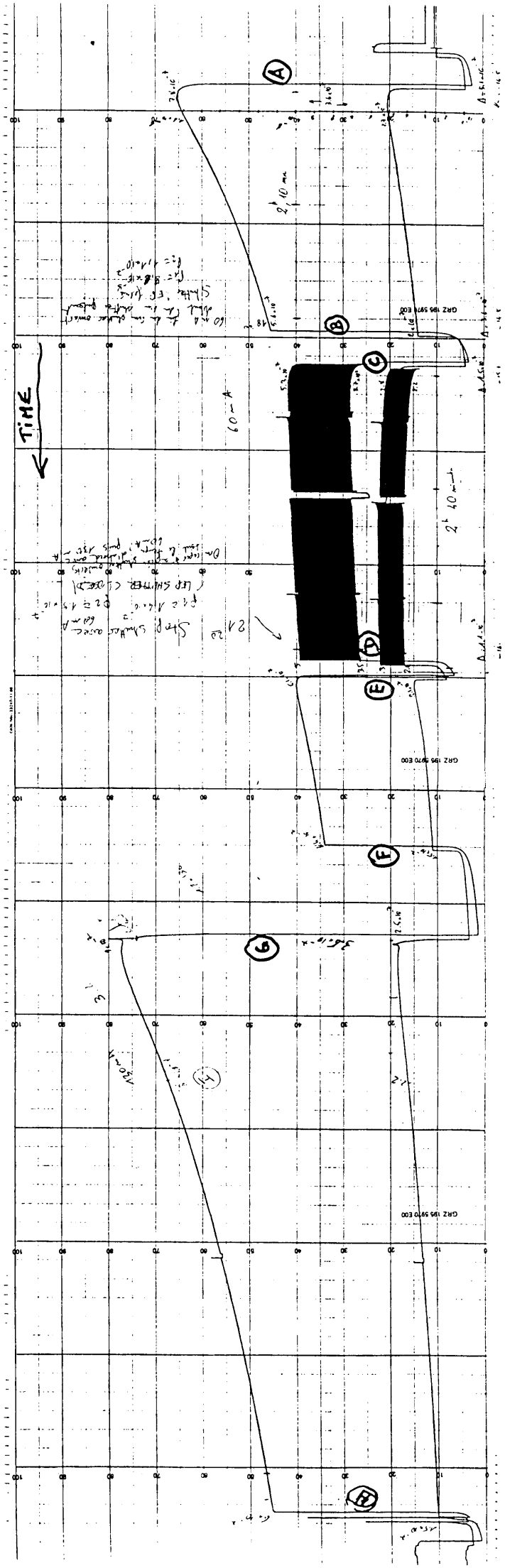


Fig. 6

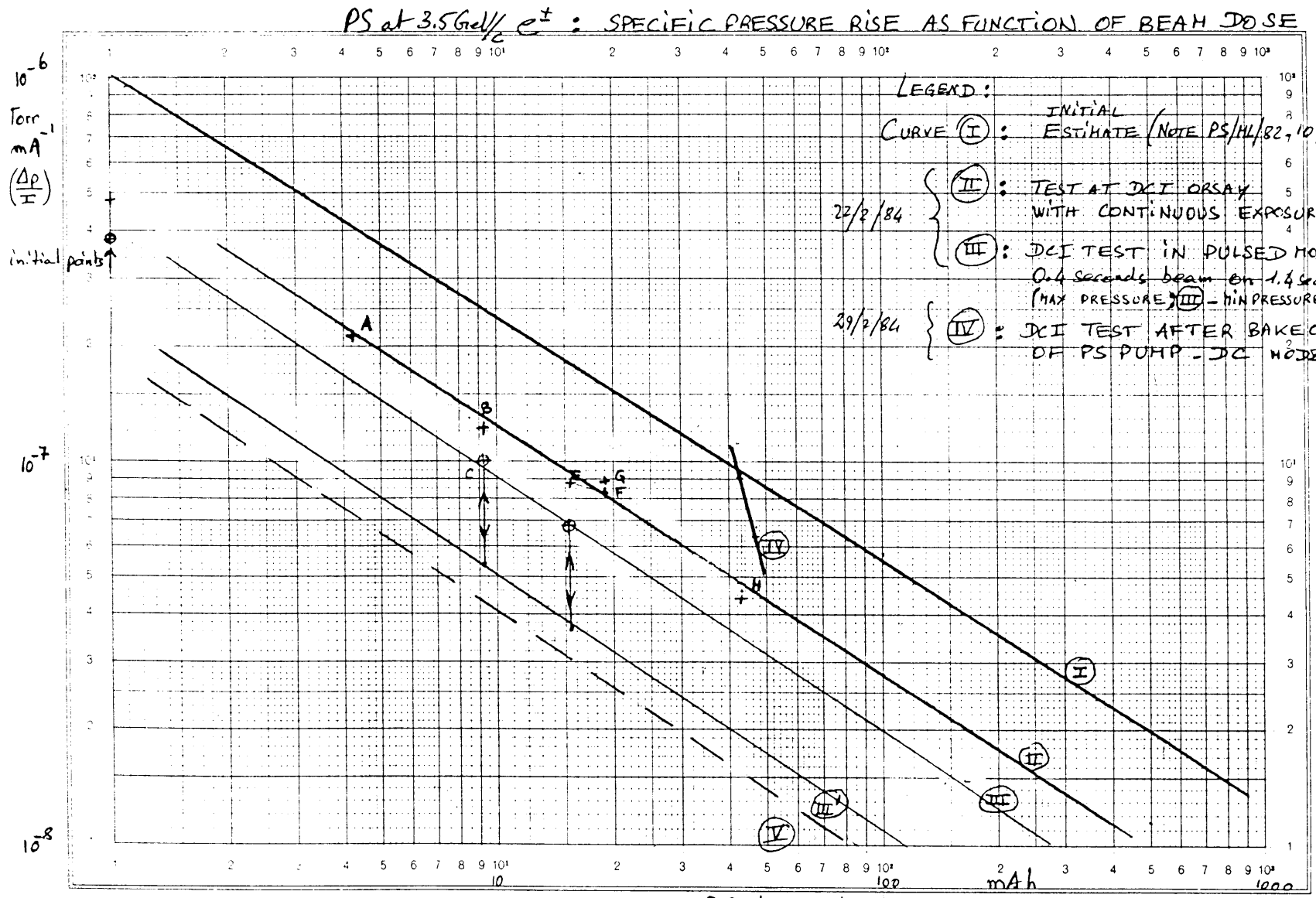

PS at 3.5 GeV/c e± : SPECIFIC PRESSURE RISE AS FUNCTION OF BEAM DOSE
LEGEND:
CURVE (I): INITIAL ESTIMATE (NOTE PS/HL/82,10)
22/2/84
(II): TEST AT DCI ORSAY WITH CONTINUOUS EXPOSURE
(III): DCI TEST IN PULSED MODE 0.4 seconds beam on 1.4 sec cycle (MAX PRESSURE (III) - MIN PRESSURE (II))
29/2/84
(IV): DCI TEST AFTER BAKE OUT OF PS PUMP - DC MODE
10⁻⁶
Torr mA⁻¹ (Δp/H)
initial points
10⁻⁷
10⁻⁸
A
B
C
D
E
F
G
H
10
100
mAh
1000
PS beam dose (not reduced by duty factor)
Logar. Teilung / Division 1-100 und 1-1000 Einheit / Unité 83,33 mm
Ed. Aerni-Leuch, Bern Nr. 552

Fig. 7

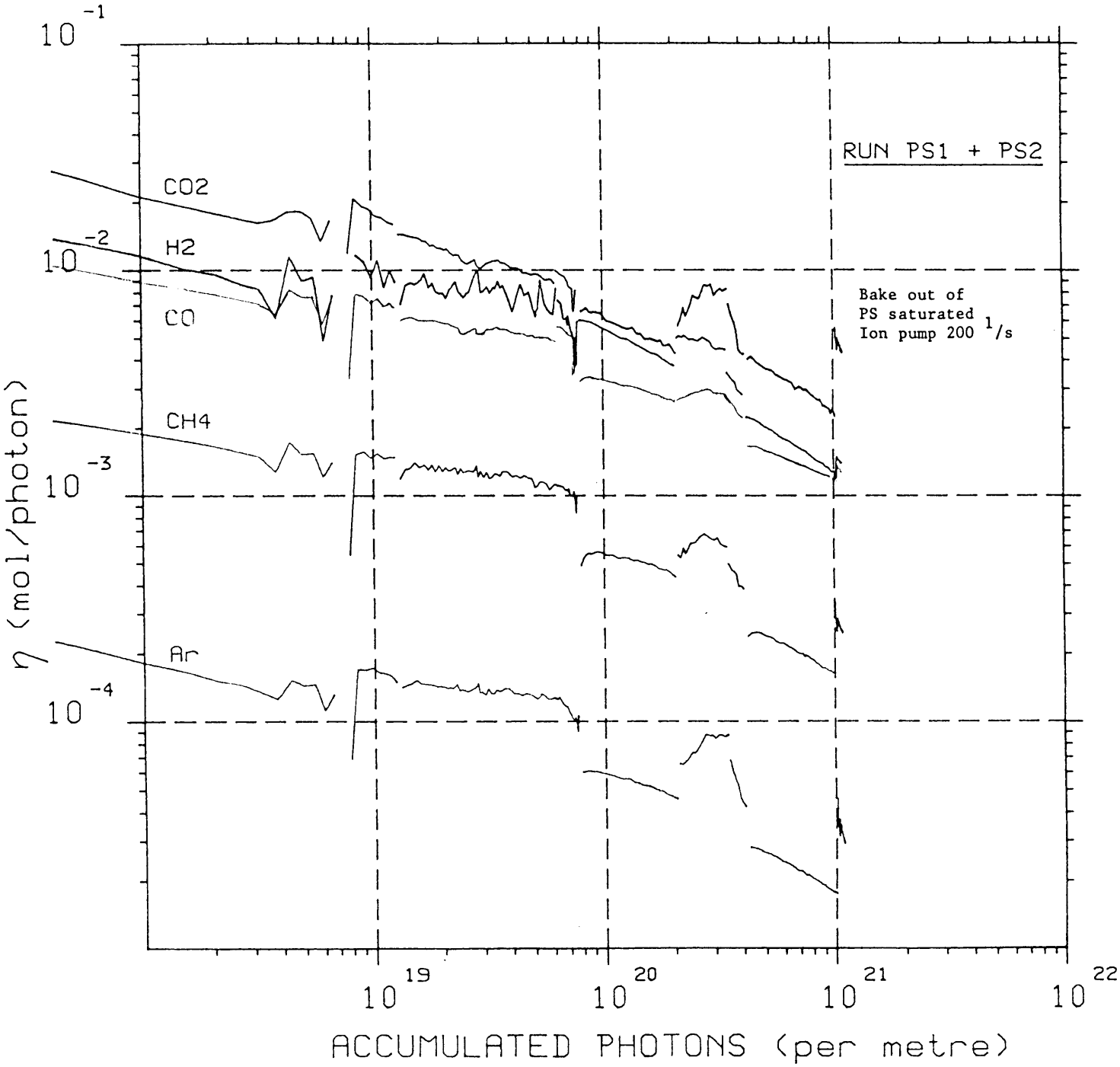

RUN PS1 + PS2
Bake out of
PS saturated
Ion pump 200 l/s
CO2
H2
CO
CH4
Ar
η (mol/photon)
ACCUMULATED PHOTONS (per metre)

Fig. 9