PS/RF/Note 93-18
30/11/93

COMPARISON BETWEEN ION AND ELECTRON CLEARING CURRENTS IN THE CERN AA WITH STORED ANTIPROTON AND PROTON BEAMS

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1. INTRODUCTION.

It has been proposed [1] to measure the CERN LHC vacuum pressure inside the cold vacuum chamber of the 10 m long bending magnets by means of measuring the electron clearing currents at both ends with a low intensity debunched proton beam circulating at injection energy. This allows detection of localised leaks that otherwise could not be detected at the ends.

It has been shown [2] that i) heating by multiple Coulomb scattering with the circulating protons is a marginal effect, and ii) only a few per cent of the electrons are born with energies large enough to escape from the potential well, so that the majority of the electrons produced by ionisation of the residual gas should be measured on the clearing electrodes.

Two experiments were done in the CERN AA to confirm this. One experiment was done in normal polarity with cooled antiprotons circulating clockwise and measuring ion currents with negative extraction potentials, another experiment was done in so called inverted polarity with cooled protons circulating clockwise and measuring electron currents with positive extraction potentials.

In both cases sections of the machine were isolated from the rest of the machine by means of barrier potentials at each end (+300 Volts for pbars, -300 Volts for protons). This prevents neutralising particles from flowing into or escaping out of the section isolated in this manner.

With an antiproton stack the total ion current of the extracting electrodes in an isolated section is constant and independent of the number of electrodes switched to the extracting potential, which indicates that the total ion production in that sector is collected on the clearing electrodes, that the ions are confined by the beam potential and the barriers at the ends, and that ions can move within the isolated sector without being lost except on the clearing electrode.

For neutralising electrons extracted from a proton beam, large variations in total clearing current from an isolated section were observed in apparent contradiction with the calculation for the LHC mentioned above.

It is important to understand the cause of this to arrive at a proper design of the LHC vacuum gauge electron clearing system. Further experiments and calculations are required to fully understand the origin of the missing or extra extracted electrons.

2. THE AA CLEARING SYSTEM.

The AA clearing system [3] is well suited to do such experiments as each electrode is equipped with a floating, guarded electrometer, which by triaxial cables and feed-throughs are connected to the clearing electrodes. The clearing and guard potentials can be switched to either ground, V_1 (generally clearing potential) or V_2 (generally barrier potential).

The clearing field is always vertical.

The clearing electrodes are of three types (see table 1):

- Polarised vertical closed orbit pick-ups (electrostatic types, UHV <xxyy>), of which one side is grounded, the other connected to the clearing potential. The coupling capacitors to the head amplifier are NOT guarded, and their leakage current and associated time constant prevent measuring of clearing currents unless the vertical head amplifiers are removed. Without head amplifiers these electrodes are similar to the coaxial type. In this case the vertical orbit cannot be measured.
- Triaxial type. Cable, microwave filter, and vacuum feed-through are all guarded triaxial structures. These have generally very low leakage currents less than a tenth of a pA with several hundred volts applied.
- Coaxial type. Some part of the electrometer to electrode connection is coaxial. They can be used for clearing current measurements if the connectors are clean and dry, but the leakage current is much higher: typically 1 to 10 pA for clearing voltages in the order of 300 - 500 volts.

3. ION CLEARING CURRENTS WITH AN ANTIPROTON STACK (20/7/93).

First an experiment was done with an isolated section from sector 20 to sector 23 using UHV2000 and UHV2310 as barrier electrodes, see figure 1. UHV2200 inside the section was connected to ground to eliminate it as a clearing electrode since its current cannot be measured due to leakage.

The total clearing current in the isolated section was then measured with only a single of the 5 good electrodes connected to the clearing potential of -450 volts, and with all 5 electrodes active, table 2, file clrcur_a.xls. The sum of the 5 clearing currents is appears to be constant within about +/- 10% for these six cases reflecting the total ion production within the isolated section.

Then an experiment was done with an isolated section almost half of the AA ring from sector 14 to sector 23 using UHV1401 and UHV2310 as barrier electrodes. UHV1600, UHV1800, UHV2000, and UHV2200 inside the section were connected to ground to eliminate them as clearing electrodes since their currents cannot be measured due to leakage.

With a stack of 5E11 antiprotons and the vacuum pressure prevailing that day, the clearing current could not be measured on a single electrode since the maximum range of the electrometers is 1 nA, and the total clearing current in the isolated section exceeded that value. There appeared to be a pressure bump of several E-9 torr in sector 21-22, see figure 2. This pressure bump is probably due to lack of sublimation. Many vacuum gauges were not operational during the experiment.

Clearing currents were measured with two electrodes only (#5 and #16, or #8 and #16), an increasing number of active electrodes or all electrodes. The sum current varies substantially, but this is most likely due to faults in the clearing system.

Electrometer #11 indicates 1 pA continuously independent of the applied voltage, possibly due to an open circuit as there was no response in neighbour electrode currents (#9 and #12) to voltage change of #11. The electrometer #11 was replaced 28/7/93 and normal behaviour was observed again.

Electrometer #9 connected to VEC1706 occasionally showed very high readings (10 times higher, range problems?). It was replaced 28/7/93 with the unused electrometer #6.

In addition, currents of electrometers #9, #12 and #13 are not reproducible for identical or similar clearing voltage configurations. This might be due to the uncontrolled potential on electrode #11.

The leakage currents of the electrodes with no beam could not be measured immediately before or after the experiment as an antiproton stack was always present.

4. ELECTRON CLEARING CURRENTS WITH A PROTON STACK (24/9/93).

The pressure distribution could not be measured as the vacuum display program crashed for unknown reasons when called.

Much setting up time in reverse polarity was lost due to the presence of the lithium lens in the target area, which caused an energy loss 3 times larger than usual of the injected protons. The synchronised PS to AA bucket to bucket transfer in mode 7 was no longer possible, and the less efficient mode 10 had to be used for stacking.

Four different potential barrier configurations were measured, table 3, file clrcur_p.xls page 1:

I: Isolated section from sector 20 to sector 23 using UHV2000 and UHV2310 as barrier electrodes. Unused UHV's grounded as usual.

II: Isolated section from sector 14 to sector 23 using UHV1401 and UHV2310 as barrier electrodes. Unused UHV's grounded as usual.

III: Isolated section from sector 22 to sector 23 using UHV2204 and UHV2310 as barrier electrodes. Active clearing with VEC2210 and/or VEC2300.

IV: Isolated section from sector 20 to sector 21 using UHV2000 and UHV2200 as barrier electrodes. Active clearing with VEC2006 and/or VEC2010.

Additionally we measured the leakage current, table 4, file clrcur_p.xls page 2:

V: +/-350 V applied and no circulating beam.

Case I. Sector 20 through 23. If the pressure is unchanged from the antiproton experiment, we would expect a total electron clearing current of (3/5)*225 pA = 135 pA in sector 20 to 23. We measure between 100 pA and 409 pA dependent on clearing voltage configuration. A large part of this variation is due to a large leakage current in VEC2204 (electrometer #18), especially when a positive potential is applied (248 pA), see leakage measurements (V) with no beam, table 4, file clrcur_p.xls page 2. Assuming the VEC2204 leakage is 70 pA at 0 V, and 248 pA at +450 V, we get a single electrode clearing current of 19 pA to 128 pA, and an all electrode current of 150 pA, far from a constant value. In most cases it appears that there is a lack of electron current.

Case II. Sector 14 through 23. In addition to the large voltage dependent leakage of VEC2204, there is a large voltage dependent leakage of VEC1701, see table 4. The sum current in the cases where these two electrodes are grounded still varies from 237 pA to 479 pA of which about 90 pA is the leakage of the above mentioned electrodes, net clearing current 147 pA to 390 pA. With all electrodes in the section active, the currents were recorded as function of the potential in the range 15 to 350 V. Except for the leaking electrodes VEC1701 and VEC2204, all electrodes show essentially constant clearing current from 50 to 350 V. A few (#16, #19 and #20) exhibit interesting variations below 50 V.

Case III. Sector 22 and 23. The total clearing current varies from 32 pA to 81 pA depending on whether one or the other or both electrodes are active. One of the two electrodes (VEC2210) exhibits some leakage (11 pA) at positive potentials. It is not excluded, that if the VEC2204 leakage is due to a parasitic electron source (ion pump?). The VEC2210 leakage could possibly be increased when a negative potential is applied to VEC2204.

Case IV. Sector 20 and 21. None of the two active electrodes (VEC2006 and VEC2010) exhibit any significant leakage with no beam. Nevertheless the total clearing current varies from 23 pA to 95 pA depending on whether one or the other or both electrodes are active. Note that the VEC2010 clearing current (18.4 pA) is independent of whether VEC2006 is active or not.

Case V. All electrodes +350 V or -350 V, no beam. One electrode (VEC1701, triax) exhibits a significant voltage dependent leakage (840 pA at 350 V), probably due to resistive leakage. Two others (VEC2204 and VEC2210) have large polarity dependent leakage, possibly due to a parasitic nearby electron source like an ion pump (to be confirmed).

5. DISCUSSION AND FURTHER EXPERIMENTS.

There is a marked difference between electron and ion clearing current. The total clearing current in an isolated section is approximately constant for ion clearing of an antiproton beam while variations up to a factor 4 has been observed for electron clearing of a proton beam as the number of active electrodes is varied.

It is important to understand the apparent loss in electron current for certain clearing configurations to make a successful design of the electron clearing system for LHC.

The AA is an ideal machine to make such measurements because of its ability to store both protons and antiprotons and it's clearing current instrumentation. More experiments in the AA with protons and antiprotons are proposed. The leaking electrodes must be fixed with no beam or the cause of parasitic electrons understood. The faulty vacuum gauges must be fixed to enable more precise logging of pressure.

Closely spaced experiments with protons and antiprotons under similar vacuum conditions should be done in March 94 to make absolute comparisons of electron and ion currents. It should be determined whether the electron currents vary because of loss of collected electrons or due to excessive electrons caused by secondary emission from electrons or ions hitting the vacuum chamber. The clearing current versus voltage should be measured for each of the 3 combinations of 2 electrodes clearing a small isolated section (cases III and IV).

The geometry of the four electrodes used in case III and IV (VEC2006, VEC2010, VEC2210, and VEC2300) should be studied to try to explain the results of sector 20/21 and sector 22/23 above.

6. REFERENCES.

[1] A. Poncet, Using the Electron Current from Ionisation of the Residual Gas by the Proton Beam to Measure the Pressure in the CERN LHC Cold Bore, private communication.

[2] P.F. Tavares, Using the Electron Current from Ionisation of the Residual Gas by the Proton Beam to Measure the Pressure in the CERN LHC Cold Bore, LNLS Note 93-??

[3] F. Pedersen, A. Poncet, L. Søby, The CERN Antiproton Accumulator Clearing System with Ion Current Measurements as a Residual Neutralisation Diagnostic, Proceedings of the 1989 IEEE Particle Accelerator Conference, Chicago, 1786 (1990).

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Electrometer Channel number	Microwave Filter Type	Filter to clearing electrode cable	Electrode connector type	Clearing electrode name	Remarks
1	triax	triax	triax	VEC1306	
2	triax	triax	triax	VEC1307	
3	coax	box	BNC	VEC1309	
4	none?	?	PU, BNC	UHV1401	
5	triax	triax	triax	VEC1500	
6	spare				
7	none?	?	PU, BNC	UHV1600	
8	triax	triax	triax	VEC1701	
9	coax	coax	coax	VEC1706	
10	none?	?	PU, BNC	UHV1800	
11	coax	coax	coax	VEC1804	
12	coax	coax	coax	VEC1901	
13	coax	coax	coax	VEC1906	
14	none?	?	PU, BNC	UHV2000	
15	coax	coax	coax	VEC2006	
16	triax	triax	triax	VEC2010	
17	none?	?	PU, BNC	UHV2200	
18	triax	triax	triax	VEC2204	
19	triax	triax	triax	VEC2210	
20	triax	triax	triax	VEC2300	
21	none?	?	PU, BNC	UHV2310	
22	spare				
23	coax	coax	coax	VEC2408	
24	coax	coax	coax	VEC2410	
25	triax	triax	triax	VEC0201	
26	none?	?	PU, BNC	UHV0202	
27	coax	coax	coax	VEC0300	
28	triax	triax	triax	VEC0305	
29	none?	?	PU, BNC	UHV0400	
30	triax	triax	triax	VEC0500	
31	coax	coax	coax	VEC0507	
32	none?	?	PU, BNC	UHV0600	
33	coax	coax	coax	VEC0605	
34	coax	coax	coax	VEC0701	
35	coax	coax	coax	VEC0706	
36	none?	?	PU, BNC	UHV0800	
37	coax	coax	coax	VEC0806	
38	triax	triax	triax	VEC0901	
39	none?	?	PU, BNC	UHV1000	
40	spare				
41	triax	triax	triax	VEC1100	
42	none?	?	PU, BNC	UHV1110	
43	coax	box	lemo	VEC1204	Damper kicker
44	coax	box	lemo	VEC1211	Damper kicker
45	coax	coax	coax	VEC1300	
46	triax	triax	triax	VEC1305?	Not connected?

Table 1. AA Ring Clearing Electrodes

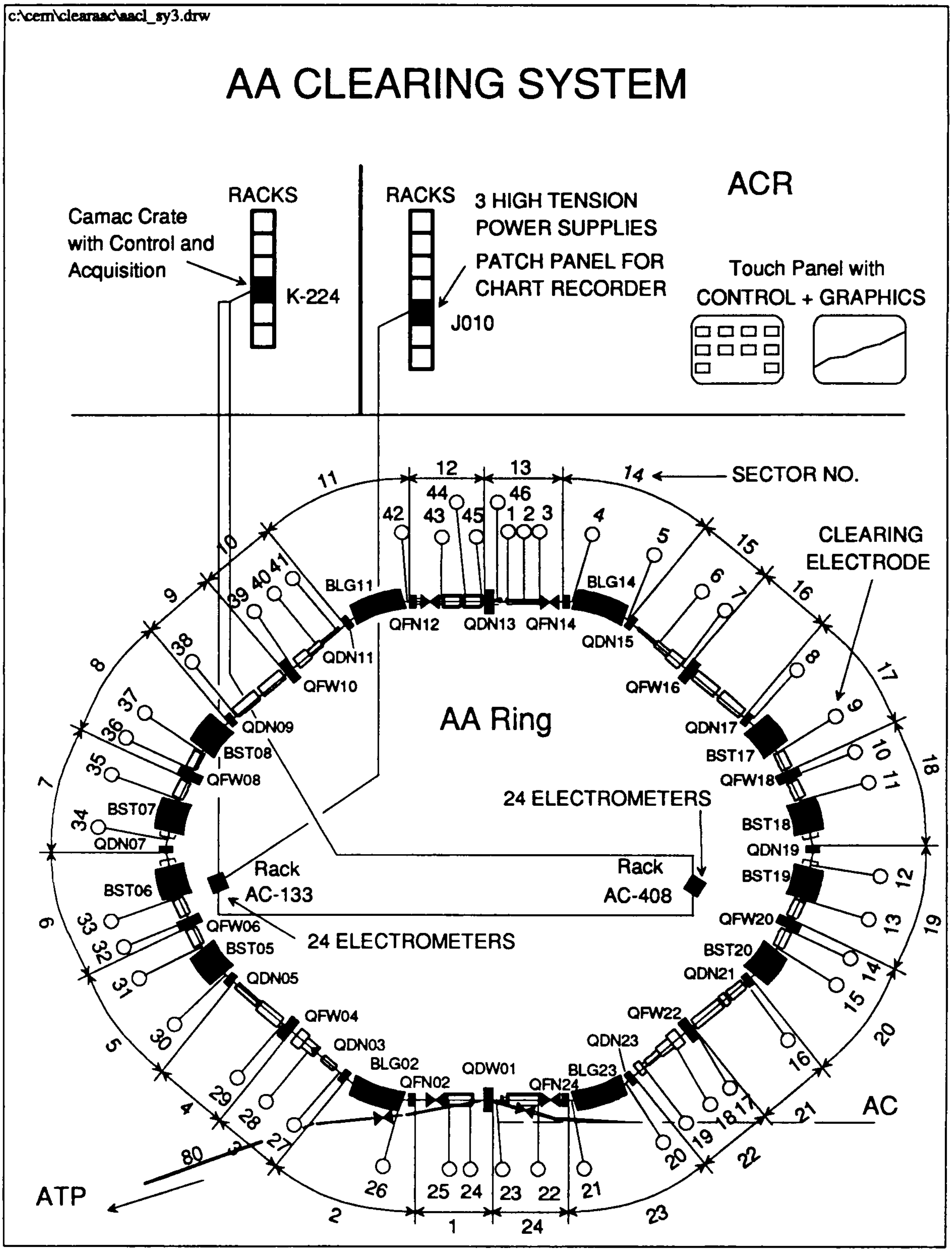

Figure 1. AA Clearing System.

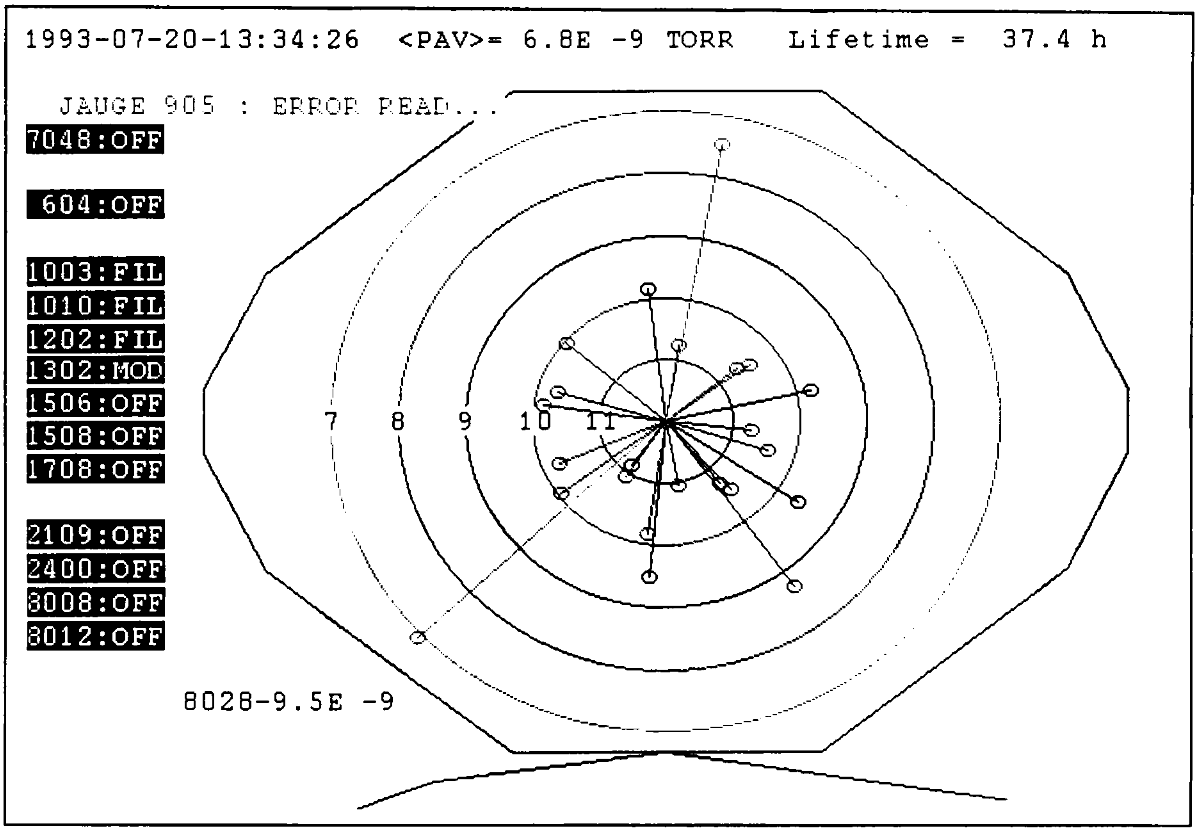

Figure 2. AA Vacuum plot 20/7/93.

STACK TUNES AND EMITTANCES
1993-07-20-12:03:54 STACK 5.02E11

	Q	95% EMITTANCE, p mm mrad	
	AT PEAK	AT PEAK	AVERAGE
HOR.	2.2544	3.8	4.0
VERT.	2.2615	.9	1.1

PEAK AT 1855.11 kHz
MEAN AT 1855.12 kHz, RMS WIDTH 97 Hz
e'_H = .14p mm mrad/min

Figure 3. AA Antiproton Stack Emittances.

AAC Machine Study on Ion Clearing Current Distribution with Antiproton Stack

V_1	-450	Active clearing (shaded)
V_2	300	Potential barrier (boxed)
GND	0	

N_p	5.02E11
E_h	4.0E-6
E_v	1.1E-6

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Clearing Potentials (V) and Clearing Currents (pA) with Antiproton Stack

4		5		7		8		9		10		11		12		13		14		15		16		17		18		19		20		21		Sum	
UHV1401		VEC1500 ****)		UHV1600		VEC1701		VEC1706 **)		UHV1800		VEC1804 *)		VEC1901		VEC1906		UHV2000		VEC2006		VEC2010		UHV2200		VEC2204 ***)		VEC2210		VEC2300		UHV2310			
pick-up		triax		pick-up		triax		coax		pick-up		coax		coax		coax		pick-up		coax		triax		pick-up		triax		triax		triax		pick-up		Current	
Curr.	Volt.	Curr.	Volt.	Curr.	Volt.	Curr.	Volt.	Curr.	Volt.	Curr.	Volt.	Curr.	Volt.	Curr.	Volt.	Curr.	Volt.	Curr.	Volt.	Curr.	Volt.	Curr.	Volt.	Curr.	Volt.	Curr.	Volt.	Curr.	Volt.	Curr.	Volt.	Curr.	Volt.		
												u/s	0					?	300	221.5	-450	3.3	0	117.9	0	18.5	0	5.9	0	1.2	0	?	300	250.4	
												u/s	0					?	300	2.8	0	195.0	-450	104.9	0	17.9	0	5.4	0	1.2	0	?	300	222.3	
												u/s	0					?	300	1.7	0	3.6	0	85.5	0	218.4	-450	4.8	0	1.0	0	?	300	229.5	
												u/s	0					?	300	1.6	0	3.6	0	81.9	0	17.5	0	219.9	-450	0.8	0	?	300	243.4	
												u/s	0					?	300	1.6	0	3.6	0	78.9	0	16.8	0	6.4	0	173.9	-450	?	300	202.3	
												u/s	0					?	300	60.1	-450	56.2	-450	?	0	22.0	-450	16.6	-450	43.0	-450	?	300	197.9	
>1 nA	300	153.3	-450	300.6	0	575.0	-450	156.3	-450	619.0	0	u/s	0	243.6	-450	273.0	-450	?	0	162.1	-450	156.8	-450	?	0	122.4	-450	219.9	-450	142.3	-450	?	300	1504.7	<= ???
>1 nA	300	558.6	-450	?	0	74.1	0	3.9	0	288.0	0	u/s	0	3.6	0	7.2	0	?	0	4.0	0	342.5	-450	?	0	16.8	0	8.1	0	1.3	0	?	300	1020.1	<= ???
>1 nA	300	152.9	-450	?	0	734.0	-450	2.6	0	?	0	u/s	0	2.8	0	4.1	0	?	0	2.3	0	340.1	-450	?	0	15.6	0	5.9	0	1.2	0	?	300	1261.5	
>1 nA	300	153.0	-450	?	0	604.1	-450	136.3	-450	?	0	u/s	0	2.6	0	3.6	0	?	0	2.0	0	337.6	-450	?	0	15.9	0	5.4	0	1.2	0	?	300	1261.7	
>1 nA	300	152.8	-450	?	0	582.9	-450	152.5	-450	?	0	u/s	0	194.3	-450	2.9	0	?	0	1.7	0	200.7	-450	?	0	15.7	0	5.2	0	1.2	0	?	300	1209.9	
>1 nA	300	153.5	-450	?	0	580.3	-450	156.8	-450	?	0	u/s	0	[illegible]	-450	131.5	-450	?	0	2.7	0	197.2	-450	?	0	15.2	0	5.0	0	1.2	0	?	300	1260.5	
>1 nA	300	153.1	-450	?	0	565.0	-450	146.5	-450	?	0	u/s	0	116.0	-450	113.3	-450	?	0	166.3	-450	152.2	-450	?	0	14.4	0	4.5	0	1.2	0	?	300	1332.5	
>1 nA	300	152.4	-450	?	0	562.8	-450	153.7	-450	?	0	u/s	0	115.4	-450	110.6	-450	?	0	164.3	-450	56.6	-450	?	0	178.5	-450	4.4	0	1.0	0	?	300	1199.7	
>1 nA	300	153.0	-450	?	0	563.2	-450	159.6	-450	?	0	u/s	0	115.7	-450	123.5	-450	?	0	162.0	-450	155.6	-450	?	0	127.5	-450	154.1	-450	0.7	0	?	300	1214.9	
>1 nA	300	152.1	-450	?	0	559.7	-450	155.4	-450	?	0	u/s	0	118.0	-450	105.5	-450	?	0	164.5	-450	156.8	-450	?	0	116.7	-450	[illegible]	-450	[illegible]	-450	?	300	1187.3	
>1 nA	300	5.3	0	?	0	969.6	-450	9.5	0	288.0	0	u/s	0	5.0	0	17.2	0	?	0	12.1	0	346.0	-450	?	0	16.7	0	5.8	0	1.3	0	?	300	1388.5	

*) Electrometer #11 indicates 1 pA continuously; no response in neighbor electrode clearing currents (#9 & #12) to voltage change (of #11). Suspect missing connection on # 11. (Repaired 28/7/93)

**) Suspect electrometer #9: ocasionally very high readings??? Electrometer #6 (unused) connected to VEC1706 as from 28/7/93.

***) Unusually large offset current??

****) Suspect scale factor error - too low sum current with #5 and #16 only.

NOTES:

1) Current transients are observed on SMACC display

2) Averaged numerical current values acquired with program (LSO)CL-SURVEY

3) The #12 and #13 currents are very much higher the first time we measure with all good electrodes ON' ??? Loose object being charged???

4) May be the large time constants involved with the pick-up head amplifier capacitors play a role.

Table 2

AAC Machine Study on Electron Clearing Current Distribution with Proton Stack

V_1	350	450
V_2	-300	-300
GND	0	0

Active clearing
Potential barrier

N_p	3.00E+11
E_h	2.9E-6
E_v	2.2E-6

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Clearing Potentials (V) and Clearing Currents (pA) with Proton Stack

4		5		7		8		6		10		11		12		13		14		15		16		17		18		19		20		21		
UHV1401		VEC1500		UHV1600		VEC1701 *)		VEC1706		UHV1800		VEC1804		VEC1901		VEC1906		UHV2000		VEC2006		VEC2010		UHV2200		VEC2204 *)		VEC2210		VEC2300		UHV2310		Sum
pick-up		triax		pick-up		triax		coax		pick-up		coax		coax		coax		pick-up		coax		triax		pick-up		triax		triax		triax		pick-up		Current
Curr.	Volt.	Curr.	Volt.	Curr.	Volt.	Curr.	Volt.	Curr.	Volt.	Curr.	Volt.	Curr.	Volt.	Curr.	Volt.	Curr.	Volt.	Curr.	Volt.	Curr.	Volt.	Curr.	Volt.	Curr.	Volt.	Curr.	Volt.	Curr.	Volt.	Curr.	Volt.	Curr.	Volt.	
																			-300	85.0	450	4.9	0	?	0	76.6	0	2.8		0.9	0		-300	170.2
																			-300	5.7	0	18.9	450	?	0	72.6	0	2.7		0.9	0		-300	100.8
																			-300	2.2	0	4.9	0	?	0	350.2	450	1.3		1.0	0		-300	359.6
																			-300	2.0	0	4.9	0	?	0	68.0	0	128.3	450	1.1	0		-300	204.3
																			-300	1.8	0	4.9	0	?	0	69.6	0	0.0		56.8	450		-300	133.1
																			-300	71.2	450	18.8	450	?	0	271.3	450	40.3	450	7.5	450		-300	409.1
	-300	65.5	350	?	0	910.7	350	22.4	350	354.3	0	31.5	350	75.8	350	64.3	350	?	0	65.7	350	18.4	350	?	0	251.5	350	48.0	350	5.6	350		-300	1559.4
	-300	90.8	350	?	0	12.9	0	39.3	350	?	0	31.2	350	75.7	350	65.0	350	?	0	65.6	350	18.4	350	?	0	248.7	350	47.9	350	5.6	350		-300	701.1
	-300	101.3	350	?	0	9.8	0	5.1	0	?	0	4.2	0	4.4	0	5.5	0	?	0	5.9	0	18.5	350	?	0	79.8	0	1.6	0	1.0	0		-300	237.1
	-300	93.4	350	?	0	8.8	0	55.6	350	?	0	1.6	0	2.8	0	1.7	0	?	0	2.9	0	18.5	350	?	0	80.6	0	2.2	0	1.0	0		-300	269.1
	-300	92.7	350	?	0	10.9	0	41.4	350	?	0	110.3	350	2.4		1.0	0	?	0	2.3	0	18.5	350	?	0	81.6	0	2.6	0	0.9	0		-300	364.6
	-300	92.2	350	?	0	10.2	0	39.8	350	?	0	33.2	350	103.3	350	0.6	0	?	0	2.1	0	18.5	350	?	0	80.5	0	2.6	0	0.9	0		-300	383.9
	-300	92.0	350	?	0	11.1	0	39.6	350	?	0	32.0	350	77.1	350	66.9	350	?	0	1.9	0	18.5	350	?	0	83.6	0	2.8	0	0.9	0		-300	426.4
	-300	92.3	350	?	0	9.5	0	39.6	350	?	0	31.8	350	76.3	350	65.8	350	?	0	68.4	350	18.4	350	?	0	83.7	0	2.9	0	0.9	0		-300	479.6
	-300	92.5	350	?	0	9.3	0	39.2	350	?	0	31.4	350	76.1	350	66.1	350	?	0	66.5	350	18.4	350	?	0	321.9	350	1.2		1.1	0		-300	723.7
	-300	92.0	350	?	0	9.2	0	39.5	350	?	0	31.6	350	76.0	350	66.1	350	?	0	66.0	350	18.4	350	?	0	266.9	350	74.8	350	1.1	0		-300	741.6
	-300	92.1	350	?	0	9.0	0	39.5	350	?	0	31.6	350	75.9	350	65.8	350	?	0	65.8	350	18.4	350	?	0	263.3	350	49.1	350	5.7	350		-300	716.2
	-300	65.3	350	?	0	975.5	350	22.8	350	354.3	0	31.5	350	75.8	350	65.9	350	?	0	65.6	350	18.4	350	?	0	262.9	350	49.0	350	5.6	350		-300	1638.3
	-300	65.0	250	?	0	677.5	250	20.5	250	354.3	0	29.5	250	71.4	250	64.2	250	?	0	62.9	250	18.1	250	?	0	243.6	250	59.5	250	4.5	250		-300	1316.7
	-300	64.3	150	?	0	428.6	150	19.7	150	354.3	0	29.3	150	65.5	150	66.8	150	?	0	60.9	150	78.0	150	?	0	213.4	150	63.1	150	4.1	150		-300	1033.7
	-300	63.7	100	?	0	305.5	100	19.7	100	354.3	0	29.0	100	65.0	100	67.5	100	?	0	60.6	100	18.0	100	?	0	196.1	100	62.9	100	4.1	100		-300	892.1
	-300	61.1	50	?	0	185.3	50	19.3	50	354.3	0	28.4	50	66.1	50	65.8	50	?	0	59.4	50	17.7	50	?	0	177.9	50	60.7	50	5.2	50		-300	746.9
	-300	57.0	30	?	0	154.6	30	19.6	30	354.3	0	28.2	30	75.2	30	65.9	30	?	0	58.1	30	16.3	30	?	0	167.0	30	40.4	30	24.2	30		-300	696.5
	-300	64.3	15	?	0	120.5	15	18.4	15	354.3	0	32.8	15	64.3	15	54.9	15	?	0	56.4	15	31.0	15	?	0	178.6	15	21.2	15	18.2	15		-300	660.6
	-300	91.0	15	?	0	11.3	0	35.2	15	354.3	0	33.1	15	64.3	15	55.4	15	?	0	56.6	15	31.1	15	?	0	176.3	15	21.4	15	18.2	15		-300	593.9
																								?	0		-300	56.1	350	5.8	350		-300	61.9
																								?	0		-300	0.3	0	32.3	350		-300	32.6
																								?	0		-300	80.6	350	1.2	0		-300	81.8
																			-300	66.4	350	18.4	350		-300									84.8
																			-300	4.6	0	18.5	350		-300									23.1
																			-300	89.7	350	5.0	0		-300									94.7

Table 3

Clearing Potentials (V) and Clearing Currents (pA) with no Beam.

4		5		7		8		6		10		11		12		13		14		15		16		17		18		19		20		21		Sum Current
UHV1401		VEC1500		UHV1600		VEC1701 *)		VEC1706		UHV1800		VEC1804		VEC1901		VEC1906		UHV2000		VEC2006		VEC2010		UHV2200		VEC2204 *)		VEC2210		VEC2300		UHV2310		
pick-up		triax		pick-up		triax		coax		pick-up		coax		coax		coax		pick-up		coax		triax		pick-up		triax		triax		triax		pick-up		
Curr.	Volt.	Curr.	Volt.	Curr.	Volt.	Curr.	Volt.	Curr.	Volt.	Curr.	Volt.	Curr.	Volt.	Curr.	Volt.	Curr.	Volt.	Curr.	Volt.	Curr.	Volt.	Curr.	Volt.	Curr.	Volt.	Curr.	Volt.	Curr.	Volt.	Curr.	Volt.	Curr.	Volt.	
		0.0	350		350	839.3	350	1.1	350		350	0.9	350	0.5	350	2.1	350		350	1.1	350	0.0	350		350	248.1	350	11.3	350	0.0	350		350	
		0.2	-350		-350	836.5	-350	4.2	-350		-350	4.0	-350	2.4	-350	5.1	-350		-350	3.2	-350	0.0	-350		-350	2.4	-350	3.1	-350	0.0	-350		-350	

*) very high leakage current
**) electrometer 9 is suspect: ocasionally very high readings. Electrometer #6 connected to VEC1706 as from 28/7/93.

NOTES:
1) Current transients are observed on SMACC display
2) Averaged numerical current values acquired with program (LSO)CL-SURVEY
3) Electrodes with coax feedthrough often have large time constants (several minutes) and some leakage.

Table 4