EXPERIMENT : Measurement of the Ion Clearing Electrode Current at Exit of BST5.

DATE : April-May June 1983

EXPERIMENTERS : A. Poncet + AA Operation crew

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Motivation

Simple curiosity. Is the ion current what it should be according to calculations ?.

Set-up

A floating potential low noise electrometer mounted in series with a regulated voltage power supply was connected onto the clearing electrode sitting at the exit of BST5. The analog output from the electrometer was fed into the vacuum Camac crate ADC unit corresponding to the nearest ion gauge, allowing direct reading from the computer.

Results

Recording of the current from the electrode as a function of the number of $\bar{p}$'s with and without the -30 volt polarisation of the electrode is shown in Fig. 1. As can be seen from Annex 1, the current on the electrode is of the order of what should be expected from residual gas ionisation by the circulating beam.

The scatter in the data, of the order of 2×10^{-11} A whatever the number of $\bar{p}$'s, is larger than the electrometer noise by almost an order of magnitude as can be seen from Fig. 2. This does not come only from some eventual residual pressure variations, as it has been observed many times. In fact, during stacking the signal is systematically higher than after a period of cooling as if one would then collect extra ions of origin other than the stack (produced for instance by the short lived electrons and secondaries ? The magnitude of the extra ion current seems to be very high). A typical time decay of the signal while cooling after stacking is shown in Fig. 3. The long term variation could be due to improvement of the vacuum consecutive to non-injection (BST5 is not too far from KPM4 and 9 which, with RF power and shutters, degas more and differently while stacking).

Figure 4 shows a recording of the clearing current for a well cooled beam as one suddenly switches off the vertical transverse feedback. The sudden signal decrease could be interpreted qualitatively as follows.

As the transverse feedback is switched off, the beam or part of the beam starts a vertical coherent instability due to the resistive wall, as it has already been observed in many occasions (see PS/AA/ME/notes 3, 8, 18), which stabilizes at amplitudes of a few mm without beam losses. After a few minutes (or a few seconds depending on the Q spread in the beam) coherence is lost due to Landau damping and switching back on the transverse feedback does not reduce the beam vertical emittance. Ions which were trapped in the beam with a kinetic energy close to the beam potential (i.e. some of those created on the edge of the cool beam) escape as soon as it decreases due to the vertical dilution resulting from the instability. However, in a matter of a few seconds -the ionisation time- the previous ion current should be restored, unless the velocity of the longitudinal drift of the ions to the clearing electrode change drastically. Inside the bending magnet BST5 the drift time, normally ~20 ms for a cool beam, would have to rise by a factor of ~200 to become comparable to the ionisation time, i.e. the electric field would have to decrease by the same factor following the instability. This may well be the case for the ions sitting in the middle of the beam, where for a hollow beam the electric field should be close to zero. In straight section 5, the longitudinal drift due to the azimuthal variation of the beam potential should not be affected by the vertical blow-up.

Figure 5 shows the evolution of the beam emittances and of the CE BST5 ion current during the same experiment. Obviously, there is no horizontal to vertical coupling at these small amplitudes, but rather anti-coupling. As shown in Annex 2 it seems unlikely that ions via multiple scattering can be the cause of any emittance reduction limitation. If the effect is real and unless there are some unlikely heating mechanisms due to ion-$\bar{p}$'s coherent oscillations, another possible cause in further horizontal cooling as the vertical emittance suddenly grows could be the reduction in the transverse intrabeam scattering consecutive to the reduction of $\bar{p}$'s density.

Further Experiments

The BST5 clearing electrode power supply has been installed temporarily in the control room, allowing remote control of the clearing potential, thus a measurement of the beam potential. A contactor in the control room will also allow the control ON/OFF of the large majority of the AA clearing electrodes. It will thus be possible to check the consequences of virtually no ion clearing on AA beam emittances.

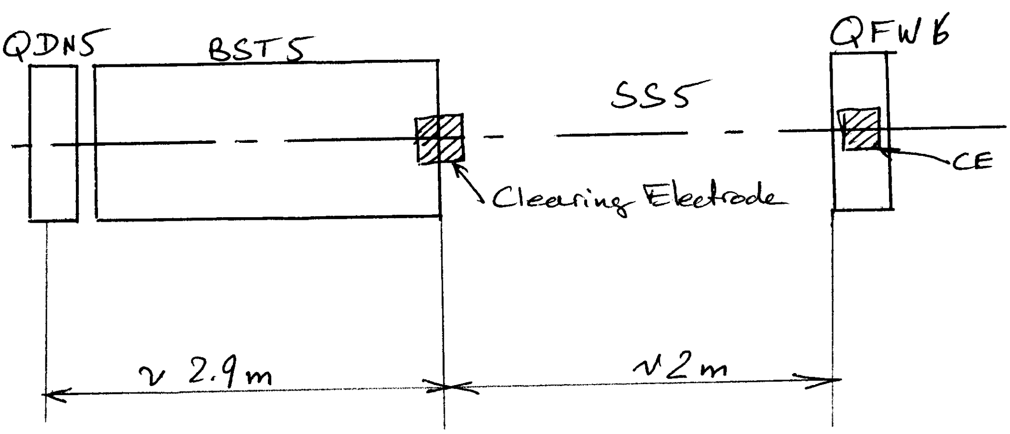
Reported by A. Poncet

1. A. Poncet, Ion Clearing in EPA, PS/ML/Note 83-1.

ANNEX 1

What should be the ion current on CE BST5 ?

Gauge pressure : 2×10^{-10} Torr; 80% H_2, 20% CO.
Ionisation time : $\tau_i \simeq 5$ s (from ISR and other work).



Assuming that CE BST5 collects half of the ions produced in SS5 and travelling into the beam potential at thermal velocities of a few 100 m/s, plus half of the ions produced in BST5 and drifting at the velocity $v \simeq E/B \simeq 200/1.4[(V/m)/Tesla]$ for $10^{11}\bar{p}$'s, the transit times are very small compared to the production times, such that there will be:

$N\bar{p}/\tau_i = 10^{11}/5 = 2 \times 10^{10}$ ions produced per second in the entire machine, of which:

$$\frac{1}{2}\left(\frac{2.9m + 2m}{157m}\right) \times 2 \times 10^{10} \simeq 3 \times 10^{8}$$ will end up on CE BST5 per second.

This gives a current of $1.6 \times 10^{-19} \cdot 3 \times 10^{8} \simeq 5 \times 10^{-11}$ A.

For a cool beam one measures $\sim 7 \times 10^{-11}$ A for 10^{11} $\bar{p}$'s, which is the right order of magnitude given the imprecision on real gas pressure and composition.

ANNEX 2

Emittance Growth Rate due to Multiple Scattering on Residual Gas or Trapped Ions for $N_{\bar{p}} = 1.65 \times 10^{11}$ and $E_{x,y} = 2\pi$ mm.mrad

a) Transverse cooling rate from Fig. 5: $1/\tau_i \simeq 3 \times 10^{-4}\ s^{-1}$.

b) Residual gas[1]: $P_G = 2 \times 10^{-10}$ Torr, 80% H_2, 20% CO:

$$\frac{1}{\tau_{MS}} \simeq P_{MS} \times 10^5$$

with $P_{MS} = 0.25\ P_g$, i.e.

$$\frac{1}{\tau_{MS}} = 5 \times 10^{-6} \ll \frac{1}{\tau_c}$$

c) Multiple scattering on trapped ions in neutralization pockets

The worst case is that of neutralization pockets. In neutralization pockets, heavy ions will dominate since their clearing times due to beam heating are much larger than light ions. Thus:

$$P_{MS} \simeq P_i$$

with the ion pressure

$$P_i = \frac{\eta\ N_{\bar{p}}}{3.24 \times 10^{22}\ 2\pi R\ E_{x,y}\bar{\beta}} \simeq 5 \times 10^{-10}\ \eta$$

η being the neutralization (ratio of ion to $\bar{p}$ charge). Thus:

$$\left(\frac{1}{\tau_{MS}}\right)_{ions} = 10^5\ P_i = 5 \times 10^{-5}\ \eta$$

even for $\eta = 1$ this is still smaller than the cooling rate $1/\tau_c$.

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1. PS/AA/EJ/78-2.

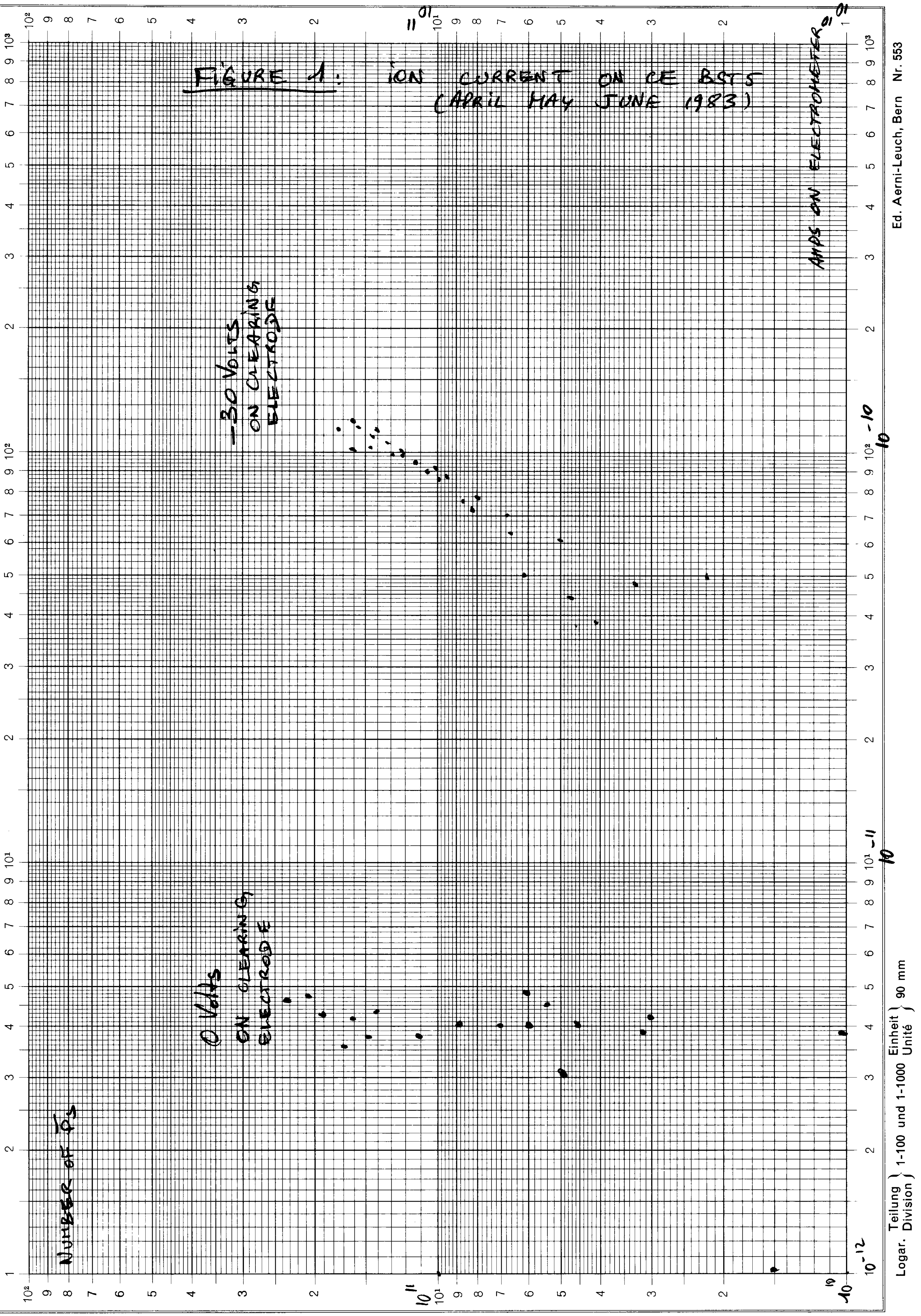
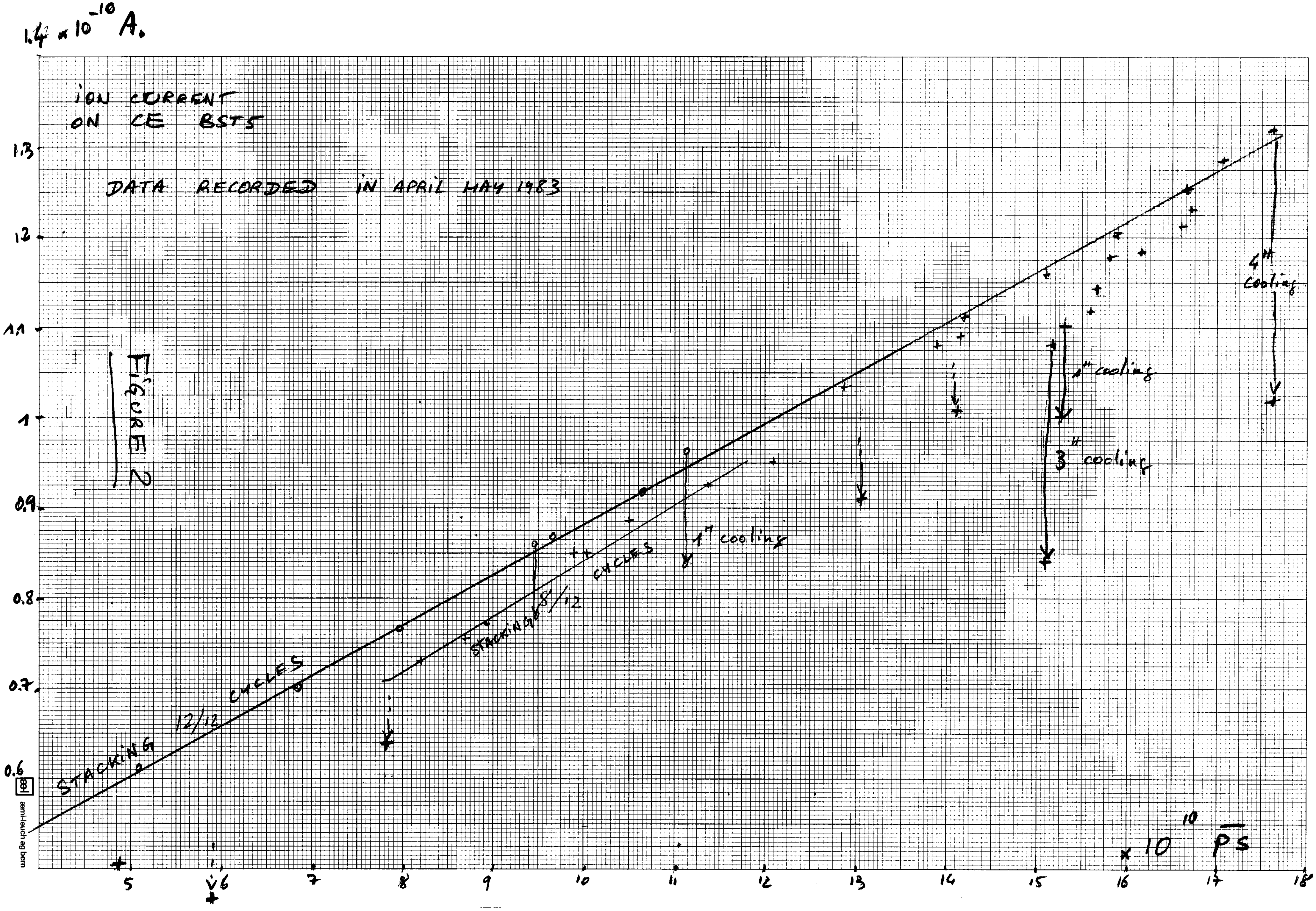


FIGURE 1: ION CURRENT ON CE BST5 (APRIL MAY JUNE 1983)


1.4 x 10^-10 A.
ION CURRENT
ON CE BST5
DATA RECORDED IN APRIL MAY 1983
FIGURE 2
STACKING 12/12 CYCLES
STACKING 8/12 CYCLES
1st cooling
3rd cooling
4th cooling
x 10^10 p̄s
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
5
6
7
8
9
10
11
12
13
14
15
16
17
18
ærni-leuch ag bern

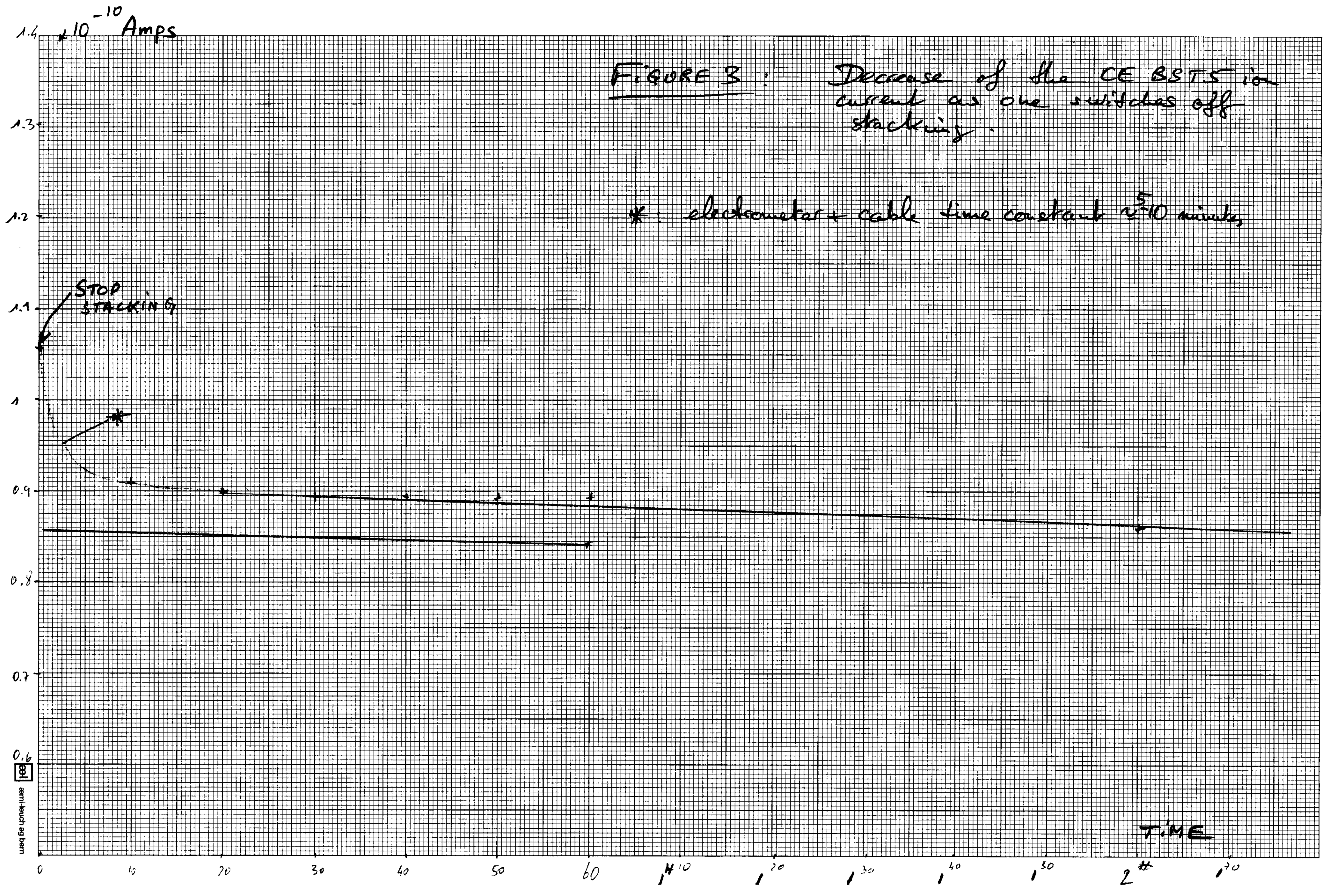
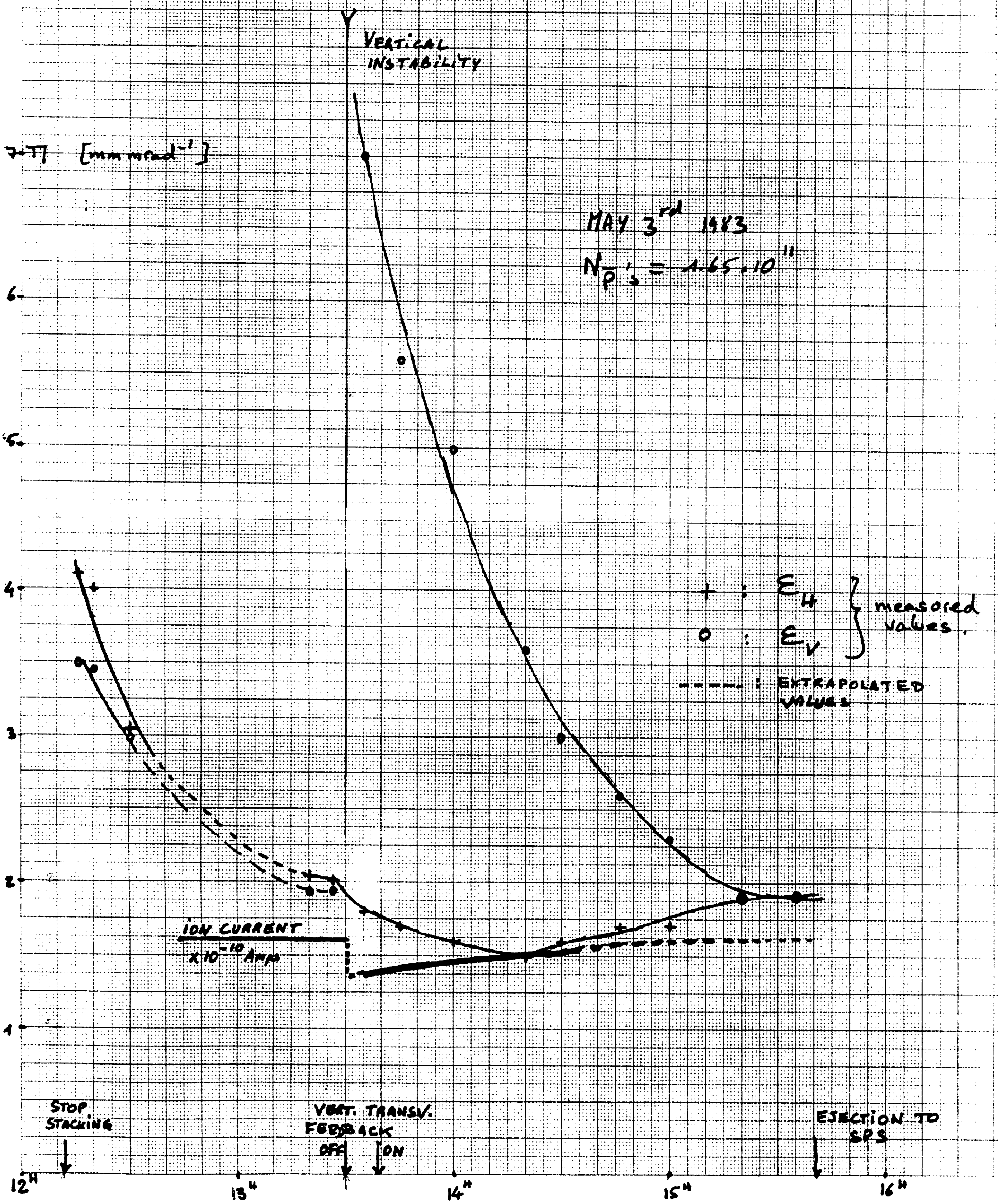


FIGURE 3: Decrease of the CE BSTS ion current as one switches off stacking.

* : electrometer + cable time constant ≈ 5–10 minutes

- FIGURE 5 -


VERTICAL INSTABILITY
πT [mm mrad⁻¹]
MAY 3rd 1983
N_p's = 1.65.10^11
+ : ε_H
o : ε_V
measured values.
- - - - : EXTRAPOLATED VALUES
ION CURRENT x10^-10 Amps
STOP STACKING
VERT. TRANSV. FEEDBACK OFF ON
EJECTION TO SPS
12^H
13^H
14^H
15^H
16^H
1
2
3
4
5
6
7

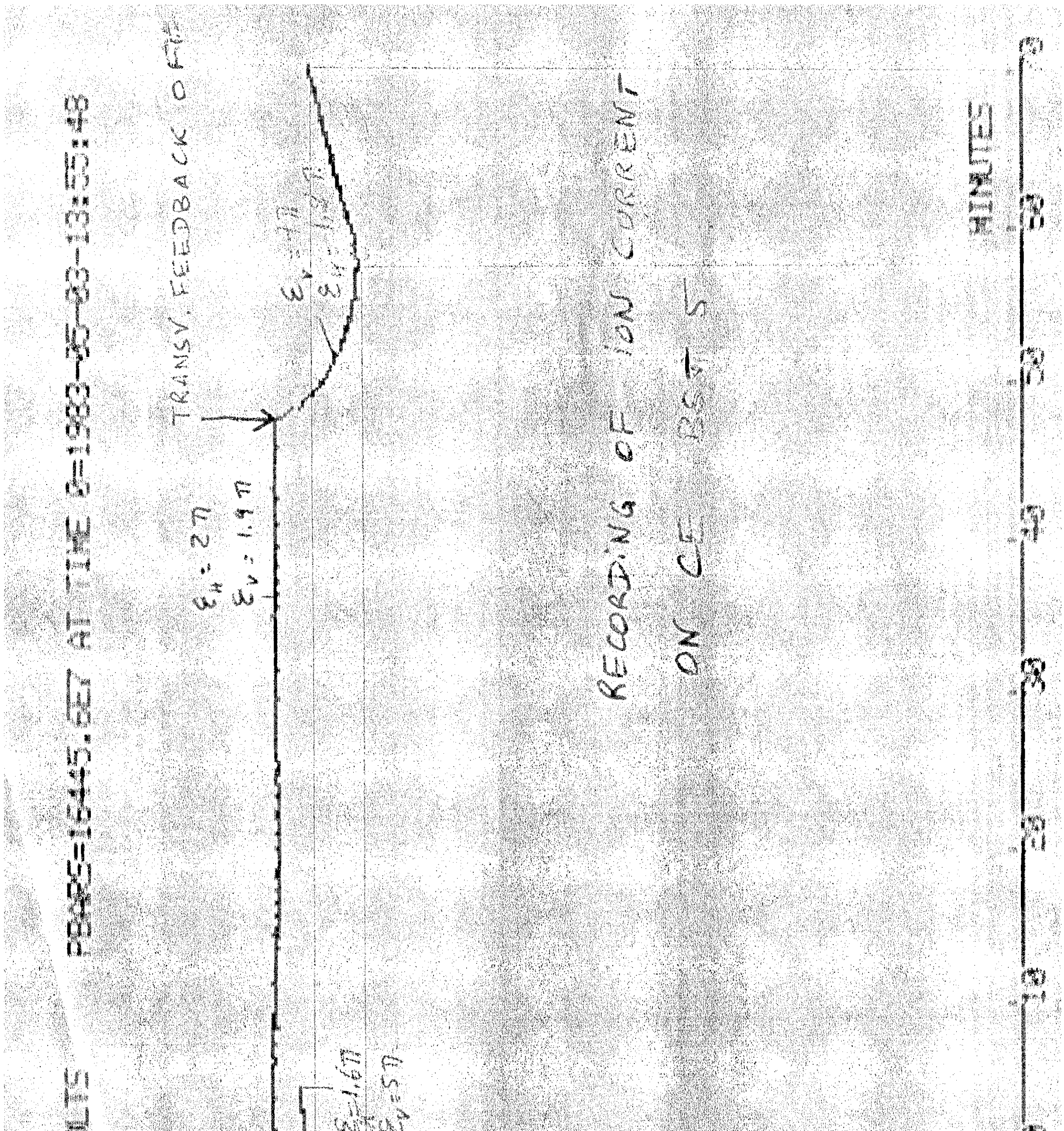

VOLTS
MINUTES
TRANSV. FEEDBACK OFF
RECORDING OF ION CURRENT

FIGURE 4