Temperature Analysis for the Hall A Cryotarget.

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03/15/1998

Abstract

In this note the cryogenic data of the Hall A cryotarget are analysed. We will provide a value of the error on the target density. After to have checked the consistency of all the temperature and pressure censors and corrected them from their offset the density error is computed. One finds 0.074% for the Hydrogen loop and 0.070% density incertainty for the Deuterium loop. A check of the cernox temperature sensors is also provided showing that one cernox in both loop one and loop two has not the same calibration than the two others. All the calibration for loop three are consistent.

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1 Introduction

The goal of this analysis is to check the temperature sensors calibration of the hall A cryotarget, to see the effect of a change of the beam current on the temperature (a beam energy change having no effect since one is far away from the minimum ionization curve and thus the energy loss is energy independant) and to estimate the errors on the temperatures. A comparison with theoritical computations will be provided.

The pressure sensor data will be also analysed and an error estimation on the pressure will be given. We will deduce the error on the density.

The Data will be analysed as well during a warm up of the cryotarget in order to check the cernox calibration.

2 Loop one

The table below gives the database names of the loop 1 temperature sensors.

sensor	device record
CTI97	haITC502_1_Sensor_1_R
CTI96	haITC502_1_Sensor_2_R
CTI93	haITC502_1_Sensor_3_R
CTI94	haITC502_4_Sensor_1_R
DTI86	haITC501_1_Sensor_1_R
DTI91	haITC501_1_Sensor_2_R
ATI95	haITC501_2_Sensor_1_R
ATI99	haITC501_2_Sensor_4_R

The figure below shows the position of these sensors.

The vapor pressure transducers are also temperature sensors. They are analysed in the paragrapher 6.

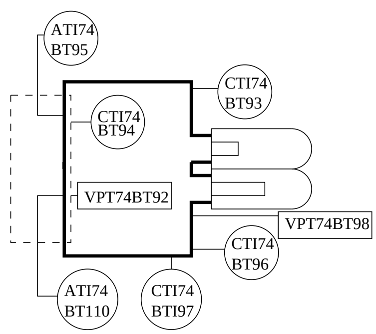

Fig. 1a. The loop one temperature sensors.

No data are available yet for the first loop.

3 Loop two

The figure below shows the location of the temperature sensors of loop 2

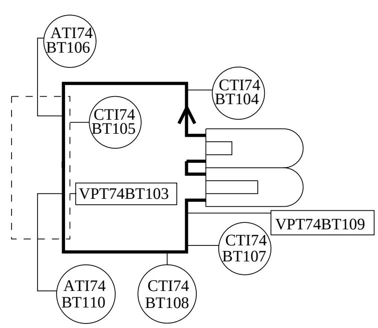

fig. 3a. Locations of the loop two temperature sensors

The table below gives the database names of the temperature sensors for loop 2.

sensor	device record	location
CTI108	haITC502_2_Sensor_1_R	before Low Power Heater
CTI107	haITC502_2_Sensor_2_R	before target cell
CTI104	haITC502_2_Sensor_3_R	after target cell
CTI105	haITC502_4_Sensor_2_R	top of heat exchanger
DTI87	haITC501_1_Sensor_3_R	coolant in
DTI90	haITC501_1_Sensor_5_R	coolant out
ATI106	haITC501_2_Sensor_2_R	top of heat exchanger
ATI110	haITC501_2_Sensor_5_R	bottom of heat exchanger

3.1 The three cernox sensors CTI104, CTI107 and CTI108

We use the runs 1020, 1083 and 1159 of the e91_026 experiment to check the loop two sensors. This loop is the liquid H_2 loop operating at 19 K. The temperature plots and a detailled analysis are given in the Annex A. We found a slight offset for sensors ITC104 and ITC108. The beam heat load is computed by comparison between the temperatures when the beam is on the target and the temperature without beam.

3.2 results

The steps of the sensor not related with current variations give the stability, i.e. the uncertainty due to the instrument.

The absolute error of the sensors was determined from a previous calibration to be 50 mK (R. Suleiman, Hall A Cryotarget Cold Calibration, http://www.jlab.org/Hall-A/equipment/targets/cryotargets/Halla_tgt.html)

The table below sums up the instability s, the absolute error R, the heat load effect on the temperature and the offsets for loop 2 (in Kelvin). This offset gives an insight of the relative error.

run	Beam effect	s	R	offset ITC104	offset ITC107	offset ITC108
1020	0.0120	<0.01	0.05	+0.01	0	+0.01
1083	0.0101	<0.01	0.05	0	0	-0.02
1159	0.0145	<0.01	0.05	0	0	0
average	0.0122	<0.01	0.05	0.003	0	-0.003

3.2.1 Error on temperature

The relative error and the stability are at least 5 time smaller than the absolute error so the total error on the temperature $\Delta temp$ is:

$\Delta temp = 0.05$ K.

3.2.2 The heat load effect

The average beam effect read on the plot 3h,3i and 3j is ΔT=0.0122 K. We have token the average of the two sensors but the warm only the downstream sensor. This implies the effect is two time greater than the one read on the plot:

ΔT= 0.0244 K.

(this value is for a 12 μA decrease of the current and a 15 cm H_2 cell). The error on this temperature shift is also $\Delta temp$.

One compares this result with a quick theoritical computation:

The energy left in the target is given by the Bethe and Bloch Formula. It provides, for a beam energy of 3.25 GeV:

$\frac{dE}{dx} = 4.8 MeV.cm^2/g$

the power left for a $10\mu A$ current in the 15 cm cell is thus

E = 50.9 W.

This power is deposed in a 0.4×0.4 ×15 cm^3volume for a 0.4 ×0.4 cm^2 rastering size.

This implies a temperature increase of 29K/s. The hydrogen flow is 1773 cm^3/s. The volume is filled in 0.00134 second thus $\Delta T_{comput} = 0.038$ K, at the same order of the experimental value. The Aluminium and Hydrogen thermal conductivities were neglected thus 0.038 K is an upper value for ΔT. This could explain why the experimental value is lower.

3.3 The other temperature sensors

The figures 3k, 3l and 3m show the temperatures of the five other loop 2 temperature sensors respectively for runs 1020, 1083 and 1159. We have checked in Annex A the consistency between the sensor behaviors, their position on the loop and the beam curent variations. The behavior of the sensor DTI87 is explained by the Joule-Thomson effect.

4 loop 3

The temperature sensor locations are given in the figure 4a.

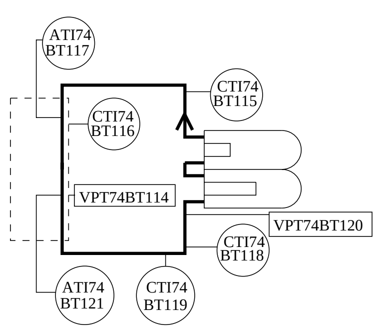

Fig. 4a. Loop three temperature sensor locations.

The table below gives the database names of the temperature sensors for loop 3.

sensor	device record	location
CTI119	haITC502_3_Sensor_1_R	before Low Power Heater
CTI118	haITC502_3_Sensor_2_R	before target cell
CTI115	haITC502_3_Sensor_3_R	after target cell
CTI116	haITC502_4_Sensor_3_R	at top of heat exchanger
DTI88	haITC501_1_Sensor_6_R	coolant in
DTI89	haITC501_1_Sensor_7_R	coolant out
ATI117	haITC501_2_Sensor_3_R	at top of heat exchanger
ATI121	haITC501_2_Sensor_6_R	at bottom of heat exchanger

4.1 The TCI115, TCI118 and TCI119 cernox sensors

The runs 1092,1126 and 1128 of e91_026 experiment were used to get the data. The cell has a 15 cm length and filled with D_2. It operates at 22 K. The analysis is provided in Annex A.

4.2 Error on temperature

The table below sums up the different errors and offsets for loop 2.

run	beam effect	s	R	offset ITC118	offset ITC119	offset ITC115
1092	...	0.0002	0.05	0.025	-0.025	0.375
1126	0.0758	0.0002	0.05	0.025	-0.025	0.375
1128	...	0.0002	0.05	0.025	-0.025	0.375
average	0.0758	0.0002	0.05	0.025	-0.025	0.375

... means the run does not allow to see the beam effect.

4.3 The other temperature sensors

The figures 4o,4p and4q show the data of the five other loop 3 temperature sensors respectively for runs 1092, 1126 and 1128. The check of the sensors consistency is provided in Annex A. Again the behaviour of the sensor near the regulation valves is explained by the Joule-Thomson effect.

5 Warm up of the cryotarget

During the warm up, the temperature ramps from about 20K to about 300 K but the range of the cernox is 3-80 K as we will see in the figures. The ramp analysis provides a check of the cernox calibration.

5.1 Loop one

Fig. 5a shows the evolution of temperatures for the three cernox CTI97, CTI108 and CTI119. The peak at 400 seconds is a misrecord of CTI19. The shift between CTI19 and CTI108 & CTI97 is not an offset but just due to the coolent (CTI108 and CTI97 are below the heat exchanger while CTI19 is above). However the non-parallelism of the CTI19 ramp and the CTI108 &CTI97 ramps indicates a slightly difference on the calibration. This conclusion assumes no change in the coolent power during the ramp. This assumption is reliable because a drift in coolent power, to explain the non parallelism, had to be constant during the 1500 seconds of ramping that is unlikely expected.

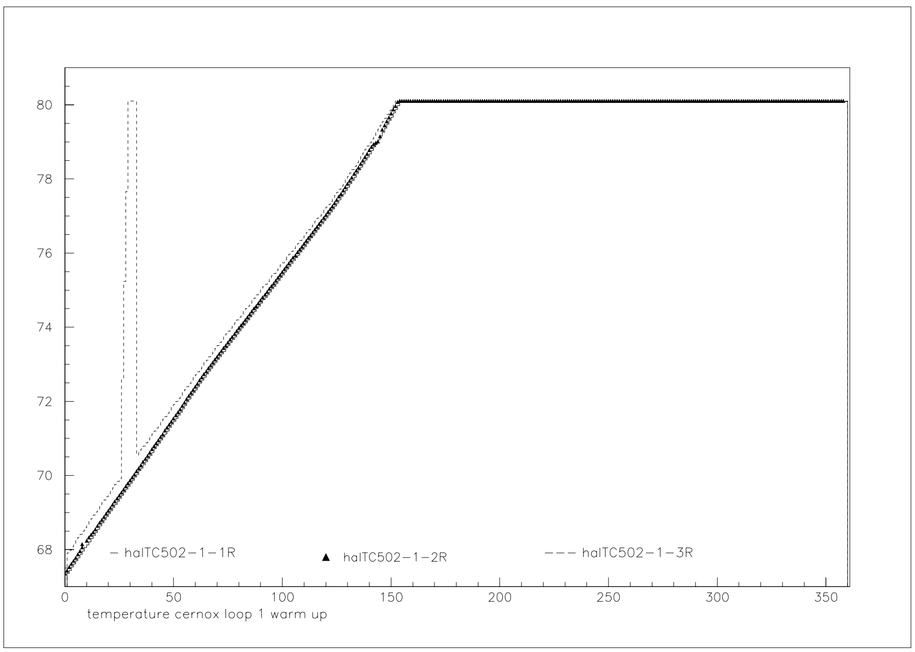

Fig. 5a. The CTI108, CTI97 and CTI119 temperatures versus time during the warm up of the cryotarget. The non parallelism of the ramps indicates a different cernox calibration.

5.2 Loop two

Fig. 5b shows the evolution of temperatures for the three cernox CTI96, CTI107 and CTI118. As for loop one the non parallelism indicates a different calibration for CTI118 and CTI 96 & CTI 107.

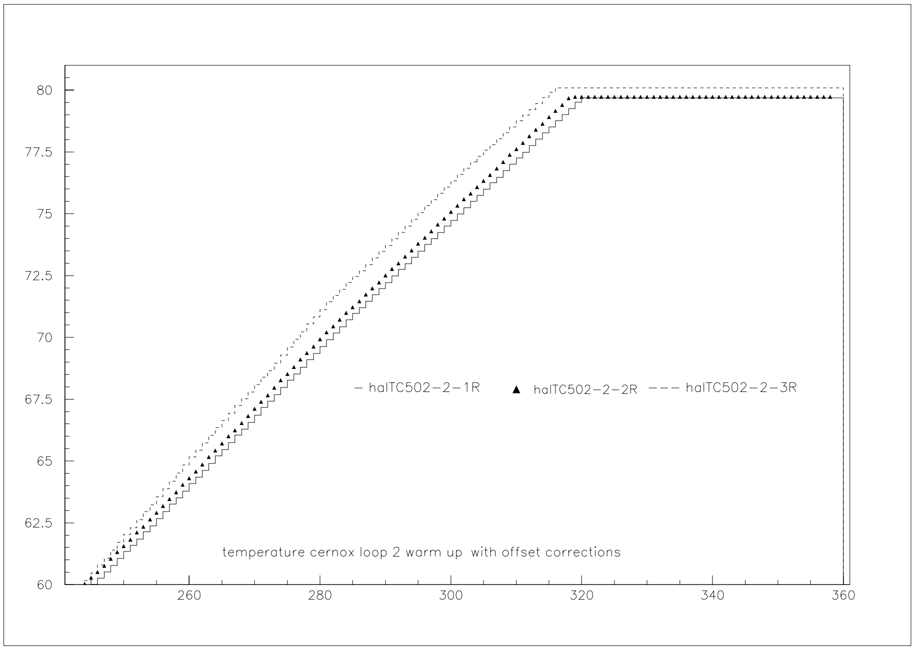

Fig. 5b. The CTI96, CTI107 and CTI118 temperatures versus time during the warm up of the cryotarget. The non parallelism of the ramps indicates a different cernox calibration.

5.3 Loop three

Fig. 5c shows the evolution of temperatures for the three cernox CTI94, CTI104 and CTI115. The three cernox have the same calibration. The drift of CTI115 during the second part of the ramp is due to coolent power fluctuation.

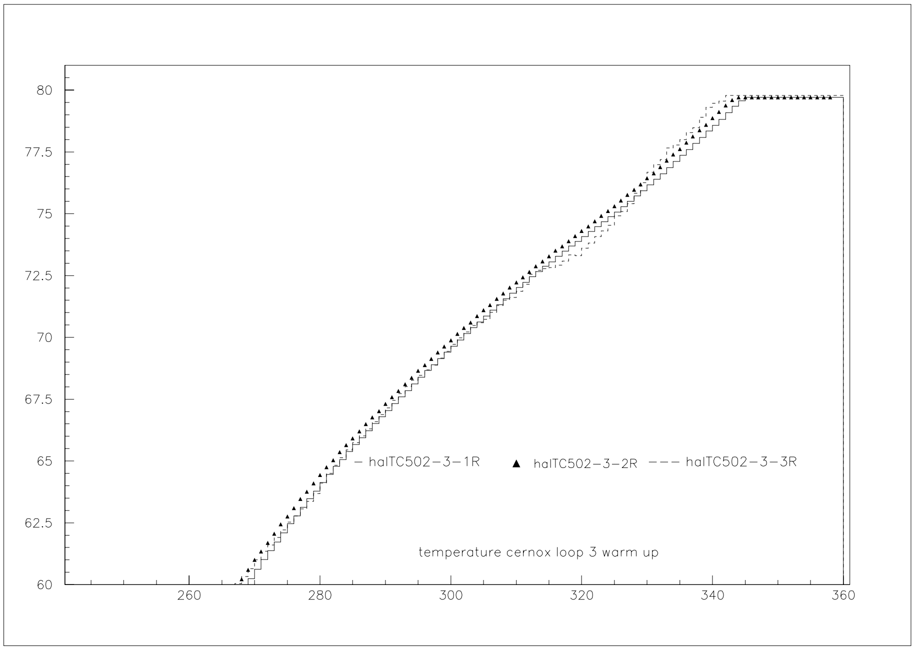

Fig. 5c. *The CTI93, CTI104 and CTI115 temperatures versus time during the warm up of the cryotarget. The cernox calibration is the same. The drift of CTI115 is due to some coolent fluctuation.*

6 Vapor pressure transducers temperature and pressure transducers pressure analysis

6.1 Loop One

No data are available yet for the first loop.

6.2 Loop Two

The two VPTs of loop two are VPT74BT103, situated near the heat exchanger and VPT74BT109 situated near the cell. The pressure is given by PT128 at the entrance of the loop and PT131 at the exit. Annex B gives a detailled analysis.

6.3 To Sum Up

The table below gives a summary of the VPT temperatures offset (in Kelvin).

run	VPT103	VPT109
1722	0.585	0.182
1728	0.585	0.182
6683	0.435	0.142
6721	0.435	0.142

The absolute (R) and relative (r) errors for the PTs are listed in the table bellow (in PSIA).

run	R PTI128	R PTI131	r PTI128	r PTI131
1722	0.25	0.25	0.0	0.01
1728	0.25	0.25	0.0	0.01
6683	0,25	0.25	0.0	0.01
6721	0.25	0.25	0.1	0.01

Thus the error on the pressure is, if we assume the cell pressure as the average of the two PTs:

$\Delta P = \frac{1}{2}(\Delta R_{PTI128} + \Delta R_{PTI131} + \Delta r_{PTI128} + \Delta r_{PTI131})$

$\Delta p = 0.36 PSIA$

6.4 Loop three

No data are available for loop three

7 Incertainty on the Density

7.1 Hydrogen

We use the data recorded in "The Thermodynamic Properties of hydrogen", National Bureau of Standards, and did a 3-points interpolation to get the error due to the temperature incertainty.

The error is :

$\Delta D_T = 5.152 \times 10^{-5}$ g/cm^3 thus a relative error of:

$\frac{\Delta D_T}{D} = 0.071$ %

We also compute the error due to the pressure incertainty. We did a linear interpolation.

$\Delta D_P = 1.9 \times 10^{-6}$ g/cm^3 thus a relative error of:

$\frac{\Delta D_P}{D} = 0.003$ %

That is a total incertainty on the density of:

$\frac{\Delta D}{D} = 0.074$ %

7.2 Deuterium

The data are taken in "The Thermodynamic Properties of deuterium", Rolf Prydz, National Bureau of Standards. We also did a 3-points interpolation for the error coming from the incertainty on temperature.

The error is :

$\Delta D_T = 5.766\times10^{-5}$ g/cm^3 thus a relative error of:

$\frac{\Delta D_T}{D}$= 0.070 %

We have no pressure data for loop 3 so we will assume the error on the pressure reading is the same as loop 2. Under this assumption, the error due to the incertainty on the pressure is:

$\Delta D_P = 8.88\times10^{-8}$ g/cm^3 thus a relative error of:

$\frac{\Delta D_P}{D}$= 0.0001 %

That is a total incertainty on the density of:

$\frac{\Delta D}{D}$= 0.070 %

8 How to Exctract the Cryogenic Data

This paragrapher gives all the steps to extract and plot the cryogenic data for the Hall A cryotarget. The parenthesis indicate a step one should not have to follow.

(-type xhost +)

-telnet hac (name: atargioc)

-type sa

-type cd $IOCS/logger

(-type cp -i *.log $LOGGER/* at the question " do you want to copy ...., answer yes to have the last record of the cryotarget.)

(-type setenv DISPLAY hostname:0.0)

-type loggergui (a window should pop up)

-hit the button "extract". Another window should pop up.

-choose one variable by clicking the name (one can choose more than one variable but one has to modify all the kumacs and the fortran codes used to plot the data). They are listed on the left side of the window. Then hit the button "add".

-choose on the righ side the hour (how many hours of data one wants to extract. One record each 10 seconds). The fortran codes and kumacs are sized for a one hour record, that is 360 records. Then choose the year, month date and hour of the run.

-hit display. The data are stored in the file "Display.dat". Bring back this file in your work dirctory. (the path on hac is /hac_epics/archive/atarg/logextract).

8.1 To plot the temperature data

This paragrapher gives a mean to plot the temperatures data. To find the necessary kumacs and the source codes, you can us the following path:

/tmp_mnt/net/farms0/work1/com97/deurpam/data_cryo

-copy the name of the first record file in un.dat, the second on deux.dat ... up to huit.dat (One has eight temperature sensors for each loop + two VPT temperature sensors. See the table below).

-copy the current file record in current.dat

-update the name of the run and the sensors in the kumacs used. (Update the size of the plot)

-add or remove (put in comment) the part taking care of the offset in the kumacs.

the table below gives the file names used by the kumacs and the usually associated content.

file used by paw	usual content (loop1, 2 and 3)
un.dat	CTI97,CTI108,CTI119
deux.dat	CTI96,CTI107,CTI118
trois.dat	CTI93,CTI104,CTI115
quatre.dat	CTI94,CTI105,CTI116
cinq.dat	DTI86,DTI87,DTI88
six.dat	DTI91,DTI90,DTI89
sept.dat	ATI95,ATI106,ATI117
huit.dat	ATI99,ATI110,ATI121
dix.dat	PTI128
onze.dat	PTI131
douze.dat	VPT103
treize.dat	VPT109
current.dat	current

The following table gives the role of the different kumacs.

.kumac	what it does in addition of the current plot.
autre_capteurs	plots the temperature in quatre.dat, cinq.dat...huit.dat.
autres_cap_av	plots quatre.dat...huit.dat divided by the average between trois.dat and deux.dat
temps_vs_aver	gives the temp. in un.dat, deux.dat and trois.dat divided by the cell temp.
rap_temp	gives un.dat/trois.dat, un.dat/deux.dat and deux.dat/trois.dat
aver_temp	plots the average between trois.dat and deux.dat i.e. the assumed cell temp.
vec_cernox	plots the temperature in un.dat, deux.dat and trois.dat
VPT_vs_av	Plots the VPT temp. divided by the cell temp.
warm_av	plots the average between deux.dat and trois.dat durring a warm up of the target
warm_cer	plots un.dat,deux.dat and trois.dat during a warm up.
warm_temp_av	plots un.dat, deux.dat, trois.dat divided by the cell temp during a warm up.

Note: All the kumacs use, via the paw command "shell" the two codes fab_vec.f and fab.vec2.f compiled on hp.

8.2 Problems

I have encountered the following problems.

No right side in the loggergui window—> hac need to be rebooted.

The dates of the data ploted do not correspond to the date entered on the right side of the loogergui window.

—> The code does not take a number bigining by a zero as a number, unless if it comprises between +/-1. For exemple 07.3 is not taken as a number but 0.73 is.

Aknowledgements: I want to thank Kathy Mc Kormick for the time spent to teach me the data extraction and to have corrected this manuscript. Thanks also to Jian-Ping Chen and Luminita Todor for there guidances and corrections.

9 Annex A. Temperature Analysys

9.1 Loop 1

9.1.1 Locations of the loop two temperature sensors

The table below gives the database names of the temperature sensors for loop 2.

sensor	device record	location
CTI108	haITC502_2_Sensor_1_R	before Low Power Heater
CTI107	haITC502_2_Sensor_2_R	before target cell
CTI104	haITC502_2_Sensor_3_R	after target cell
CTI105	haITC502_4_Sensor_2_R	top of heat exchanger
DTI87	haITC501_1_Sensor_3_R	coolant in
DTI90	haITC501_1_Sensor_5_R	coolant out
ATI106	haITC501_2_Sensor_2_R	top of heat exchanger
ATI110	haITC501_2_Sensor_5_R	bottom of heat exchanger

9.1.2 The three cernox sensors CTI104, CTI107 and CTI108

We use the runs 1020, 1083 and 1159 of the e91_026 experiment to check the loop two sensors. This loop is the liquid H_2 loop operating at 19 K.

fig. 3b shows the record of the three cernox sensors CTI104, CTI107 and CTI108 during run 1020. Horizontal axis is the time. The unit is ten seconds so we have data for one hour. The horizontal scale remains the same for all the figures of this note. Vertical axis gives the temperature in Kelvin for the first plot and the beam current in microAmpere for the second plot.

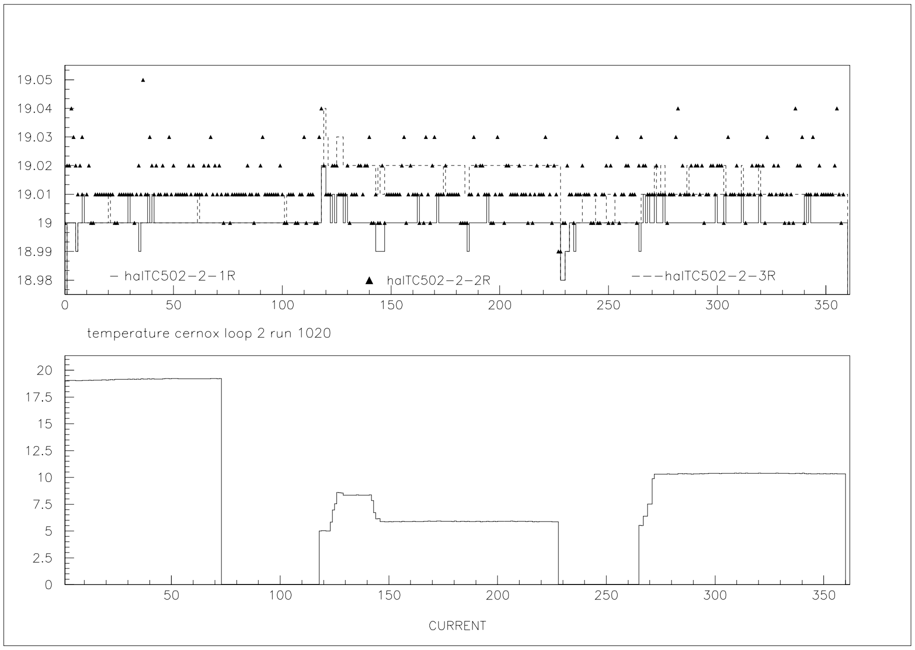

Fig. 3b. The temperatures of the three cernox CTI 108, CTI 107 and CTI 104 and the current versus time for run 1020. The vertical units are Kelvin and Micro Ampere while one horizontal unit represents 10 seconds. Each plot represents one hour of data. During the first 1190 seconds the beam was not on loop2.

During the first 1190 seconds the beam was on the aluminium target then it came on loop 2. We can see that the temperatures given by the three sensors are quite the same. However there is a little shift of 0.025 K for CTI104 that can be due to an offset and/or the fact that the sensor is downstream the cell and thus a little warmer.

Fig 3c and 3d, show the same plots respectively for runs 1083 and 1159.

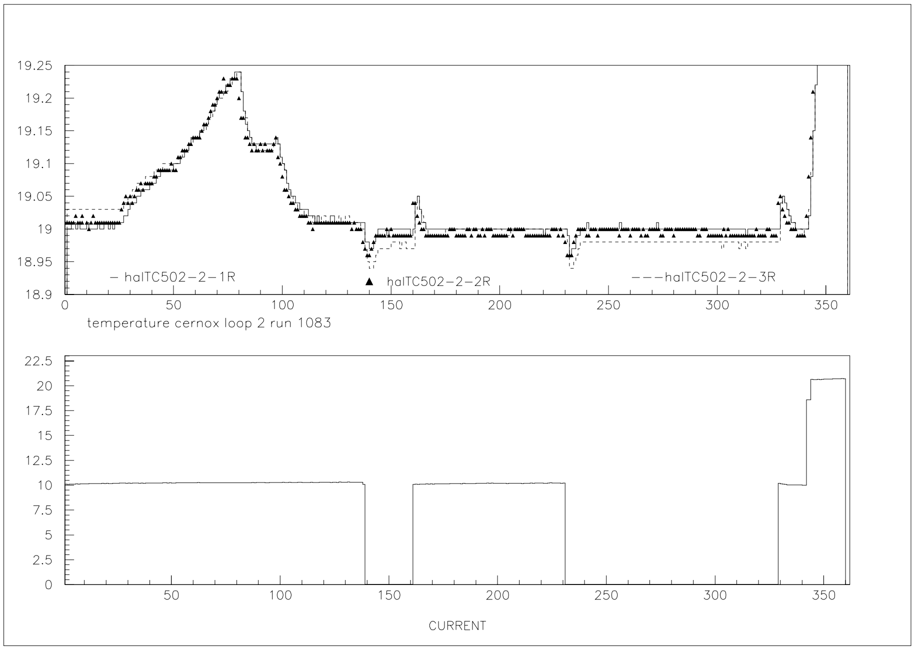

Fig. 3c. The temperatures of the three cernox CTI 108, CTI 107 and CTI 104 and the current for run 1083. The peak between 300 and 1000 seconds is due to fluctuations of the coolent tempearature

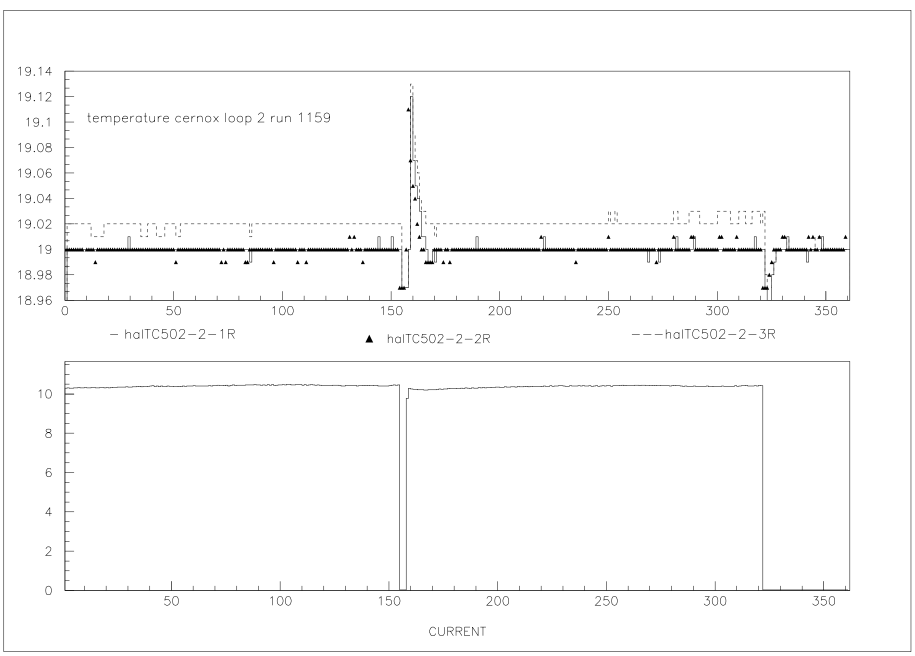

Fig. 3d. The temperatures of the three cernox CTI 108, CTI 107 and CTI 104

and the current for run 1159.

When the beam is down or not on the cell, all the sensors agree with each other within 0.02 K.

We can also see the correlation between the variation of temperature and the variation of the beam current. This variation is small for fig. 3b but existent. The peak between 500 and 1000 seconds on figure 3c is not correlated with a current jump but comes from an insufficient cooling due to fluctuation of coolant from the End Station Refrigeration. We assume the temperature in the cell is the average of the cernox ITC 107 and ITC 104 temperatures: due to the strong thermal insulation and the position of the sensors there is no loss or load (except from the beam) of heat.

In fig. 3e, 3f and 3g are plotted respectively the ITC 108, ITC 107, ITC105 temperatures divided by the temperature average between ITC 107 and ITC 104 (i.e. the temperature assumed at the cell) and the current. This shows the relative offset of each sensors, in the absence of the beam, and the shift due to the heat load in the presence of the beam. The worst relative offset is 0f 0.0006 that is 0.01 K (run 1159). This is below the range of uncertainty of the cernox.

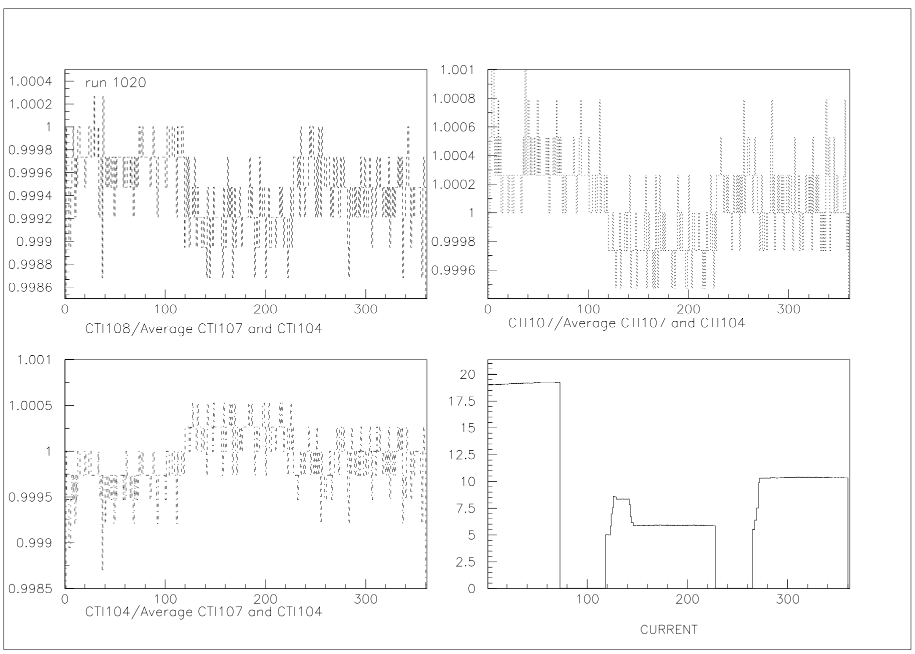

Fig. 3e. Current and cernox temperatures divided by the temperature assumed at the cell for run 1020 (versus time).

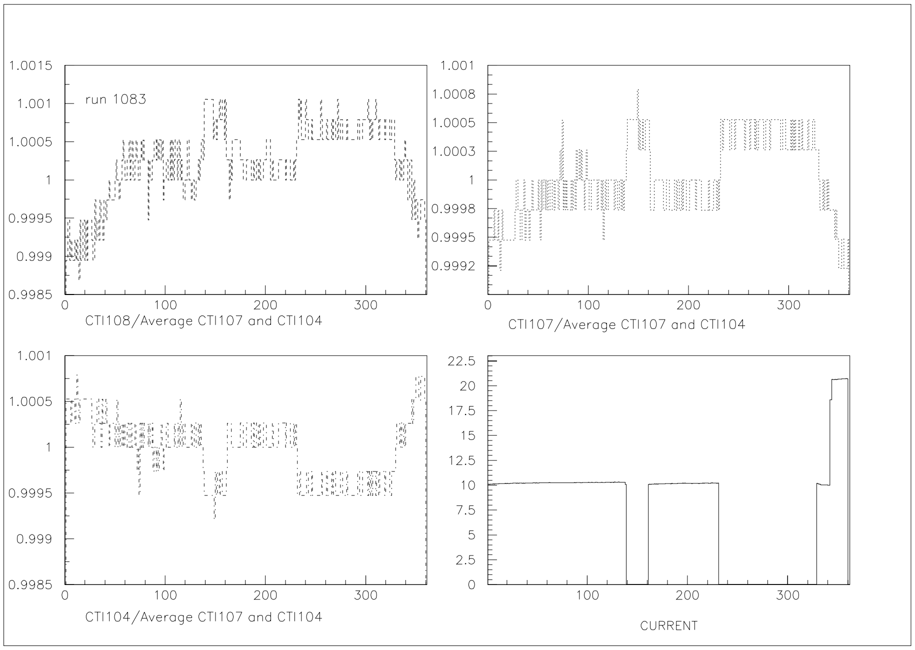

Fig. 3f.Current and cernox temperatures divided by the temperature assumed at the cell for run 1083.

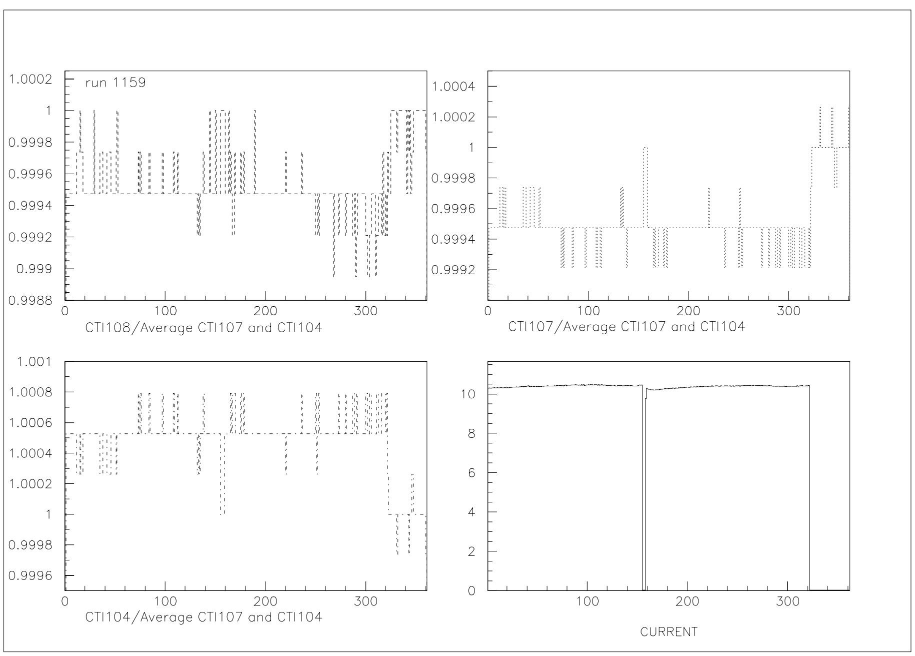

Fig. 3g. Current and cernox temperatures divided by the temperature assumed

at the cell for run 1020.

As in the previous figures, we see the correlation between the current and temperature changes. The ratio of the downstream temperatures (ITC108 and ITC107) divided by the cell temperature increase when the beam go off and the upstream temperature (ITC104) divided by the cell temperature decreases as it should be.

Fig 3h, 3i and 3j plot the average temperature between ITC108 and ITC107, wich is used to determine the temperatures at the cell, and the current for runs 1020, 1083 and 1159. They allow the computation of the shift in temperature at the cell thus the density variation with the 10 μA current (table below).

run	ΔT (K)
1020	0.0121
1083	0.0101
1159	0.0145

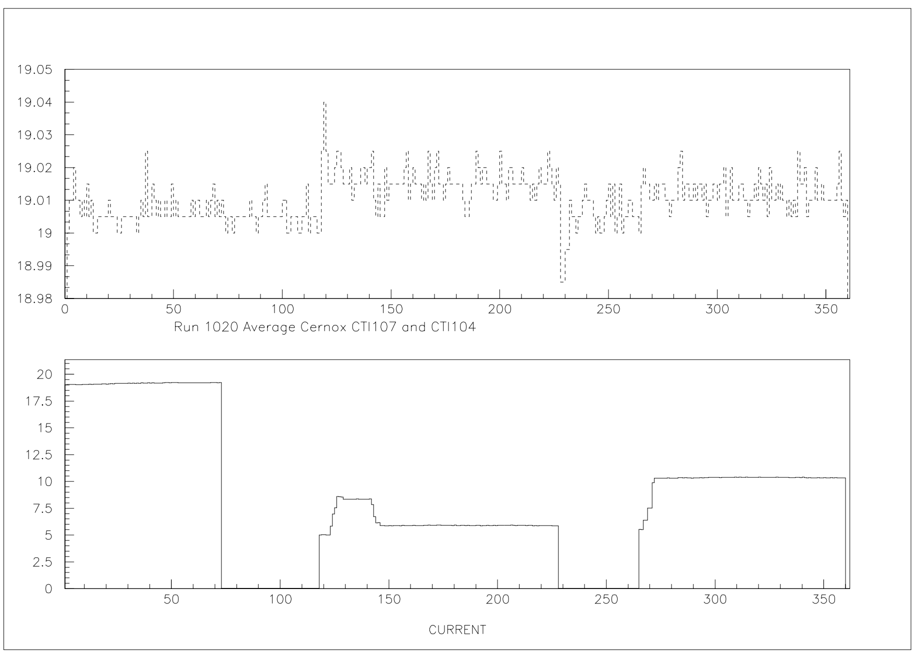

Fig. 3h. Temperature at the cell and current versus time for run 1020.

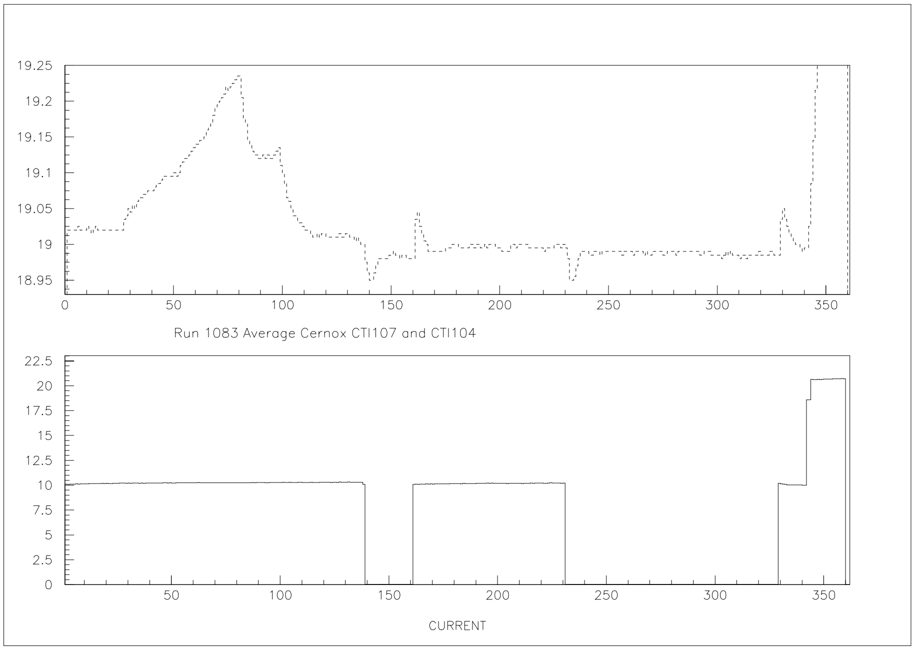

Fig. 3i. Temperature at the cell and current versus time for run 1083. The wide peak comes from refrigeration problems.

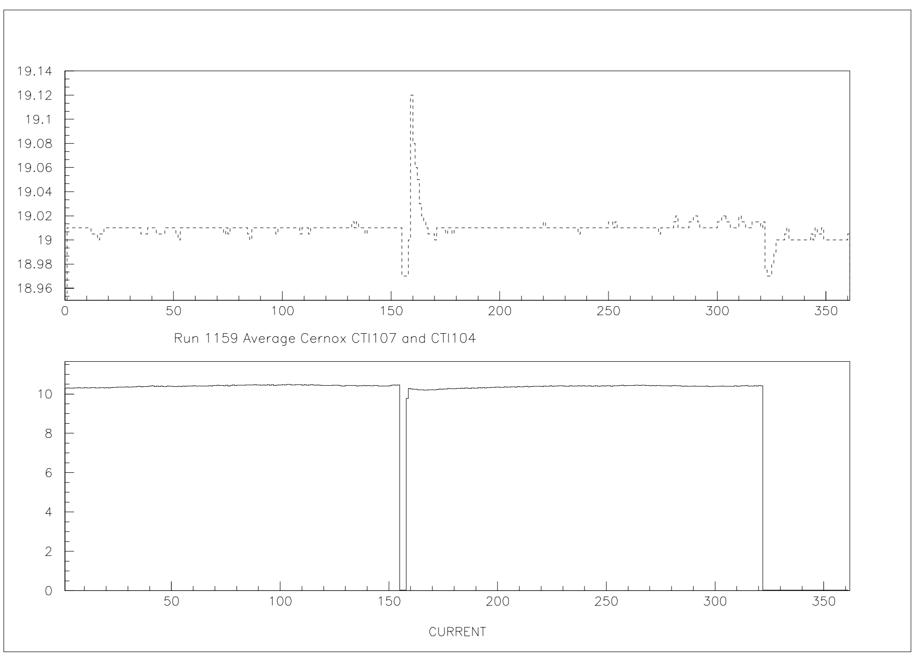

Fig. 3j. Temperature at the cell and current versus time for run 1159.

9.1.3 results

The steps of the sensor not related with current variations give the stability, i.e. the uncertainty due to the instrument.

The absolute error of the sensors was determined from a previous calibration to be 50 mK (R. Suleiman, Hall A Cryotarget Cold Calibration, http://www.jlab.org/Hall-A/equipment/targets/cryotargets/Halla_tgt.html)

The table below sums up the instability s, the absolute error R, the heat load effect on the temperature and the offsets for loop 2 (in Kelvin). This offset gives an insight of the relative error.

run	Beam effect	s	R	offset ITC104	offset ITC107	offset ITC108
1020	0.0120	$<$0.01	0.05	+0.01	0	+0.01
1083	0.0101	$<$0.01	0.05	0	0	-0.02
1159	0.0145	$<$0.01	0.05	0	0	0
average	0.0122	$<$0.01	0.05	0.003	0	-0.003

9.1.4 Error on temperature

The relative error and the stability are at least 5 time smaller than the absolute error so the total error on the temperature $\Delta temp$ is:

$\Delta temp = 0.05$ K.

9.1.5 The other temperature sensors

The figures 3k, 3l and 3m show the temperatures of the five other loop 2 temperature sensors respectively for runs 1020, 1083 and 1159. The top left plot corresponds to the Cernox sensor CTI105, the top right plot corresponds to the diode sensor DTI87, the middle left plot is for the diode sensor DTI90, the bottom left is for ATI110 and the last plot is the current (the middle right the Allen Bradley sensor ATI106 wich was not working).

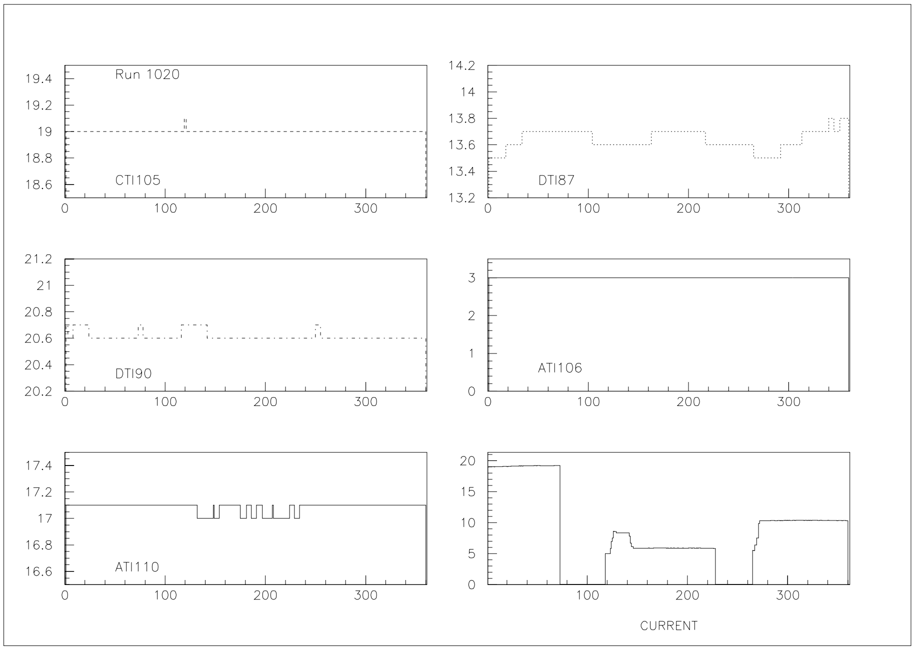

Fig. 3k. CTI105, DTI87, DTI90 and ATI100 temperature data and current versus time for the run 1020. The sensor ATI 106 is not working

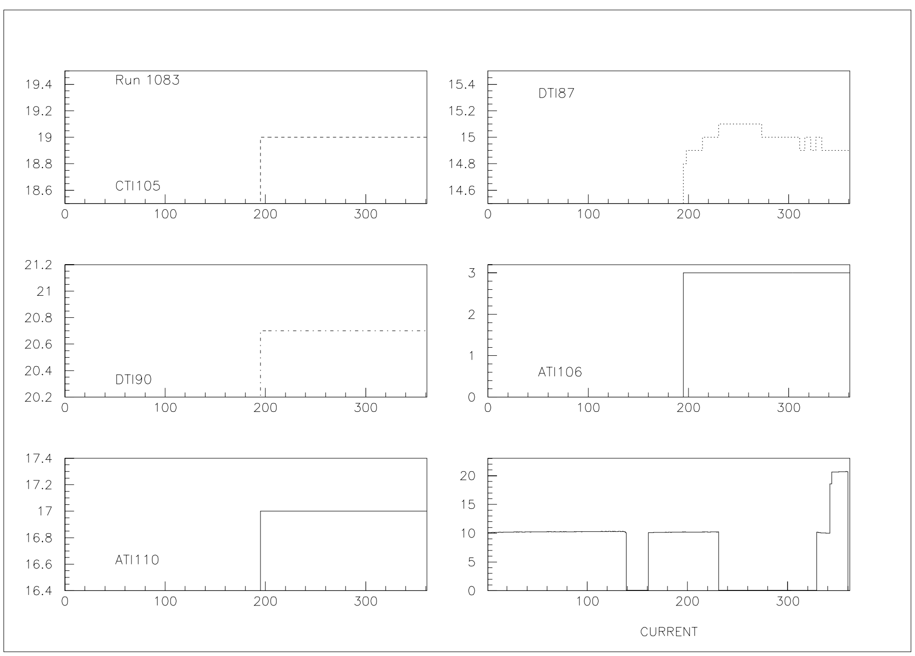

Fig. 3l. CTI105, DTI87, DTI90 and ATI100 temperature data and current

versus time for the run 1083. The sensor ATI 106 is not working. All the data are available only after 1950 seconds.

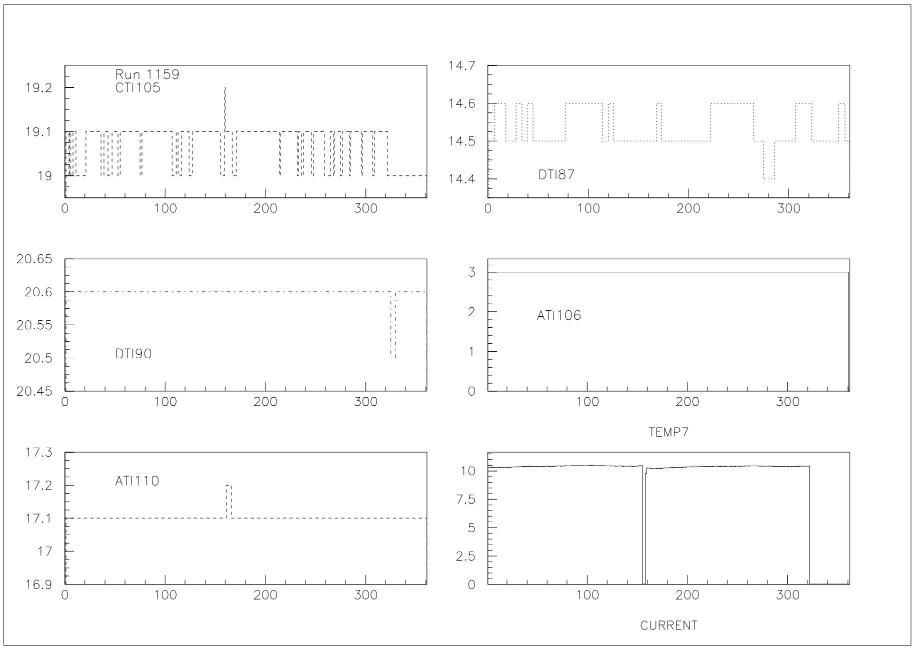

Fig. 3m. CTI105, DTI87, DTI90 and ATI100 temperature data and current versus time for the run 1159. The sensor ATI 106 is not working

For the run 1083 the data were not recorded until 1950 seconds. The diode sensor DTI87 indicates the temperature of the entering coolent fluid and DTI90 indicates the temperature of the outgoing coolent helium. CTI105 is situated before the heat exchanger while ATI110 is situated after. All the temperatures of these sensors are consistent with their location.

We can see the effect of a beam change only in run 1020. The effect is small because of the low variation of current (10 μA). The only sensor accurate enough to see the effect is ITC105 which increases when the current increases that is consistent with the position of this sensor.

We must check if the variations of temperature is consistent with the sensors positions with a run at higher current.

Fig 3n gives the run 1020's temperatures divided by the assumed cell temperature. This allow to check if the ratio variation is consistent with the position of the sensors.

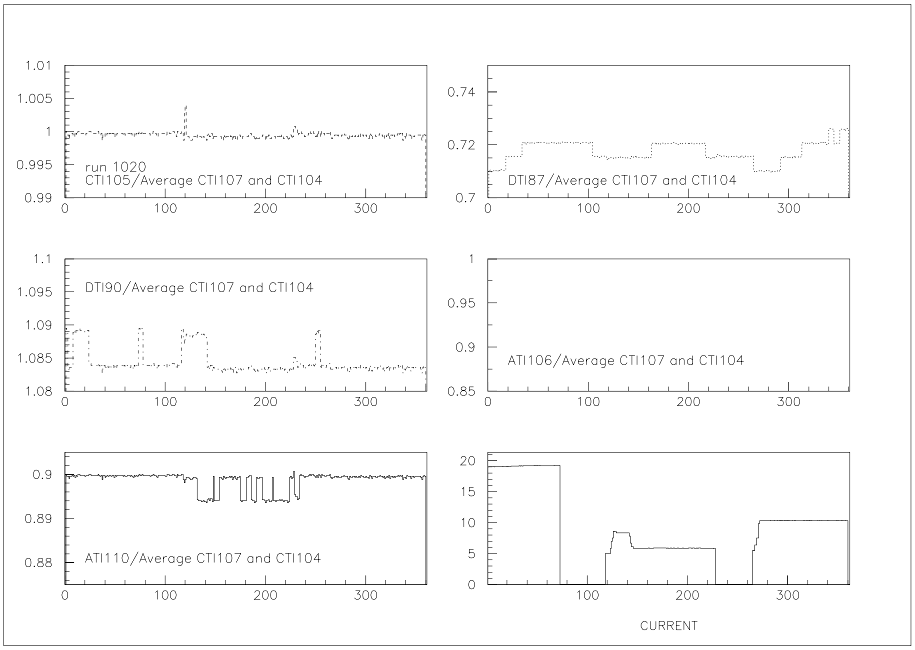

Fig. 3n. CTI105, DTI87, DTI90 and ATI100 temperature data divided by the temperature at the cell and current versus time for the run 1020. The sensor ATI 106 is not working

The first plot on the left and the second on the left increase with an increase of the current that is consistent with there position since CTI105 is between the heat load and the heat exchanger and since DTI90 is the outgoing coolent. ATI110 is after the heat exchanger and thus deacreases when the beam increases.

The DTI87 sensor must have no variations with the current since it monitors the temperature of the incoming coolent but as we will see better with the fig. 4p, it has still a variation related to the Joule-Thomson effect (see page 34).

9.2 loop 3

9.2.1 The TCI115, TCI118 and TCI119 cernox sensors

The runs 1092,1126 and 1128 of e91_026 experiment were used to get the data. The cell has a 15 cm length and filled with D_2. It operates at 22 K. The graphs 4b, 4c and 4d show the temperatures of the three cernox ITC115, ITC118 and ITC109 and the current versus time. The scale is the same as previously. Again we see the correlation between the current and the temperature as for loop 2. The effect is more important because the beam current is 100 μA instead of 10 μA.One notices in fig. 4b that CTI115 has an important offset of about 0.4 K. This shift is reduced at 0.2 K when the beam is on the cell. Fig 4c and 4d are consistent with these values. CTI118 and CTI119 indicates the same temperature with a difference of 0.05 K.

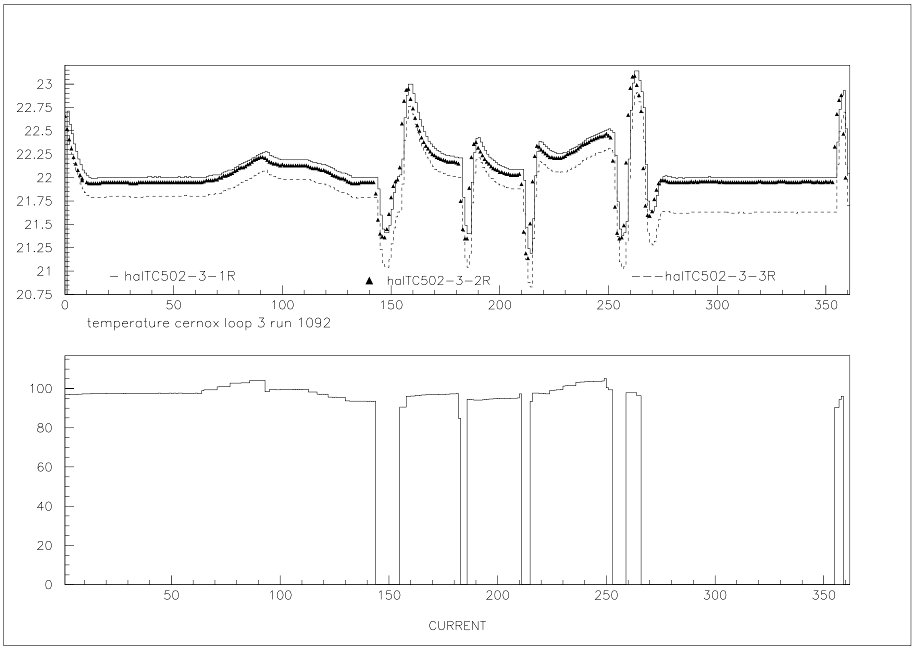

Fig. 4b. The temperatures of the three cernox CTI 119, CTI 118 and CTI 115 and the current versus time for run 1092.

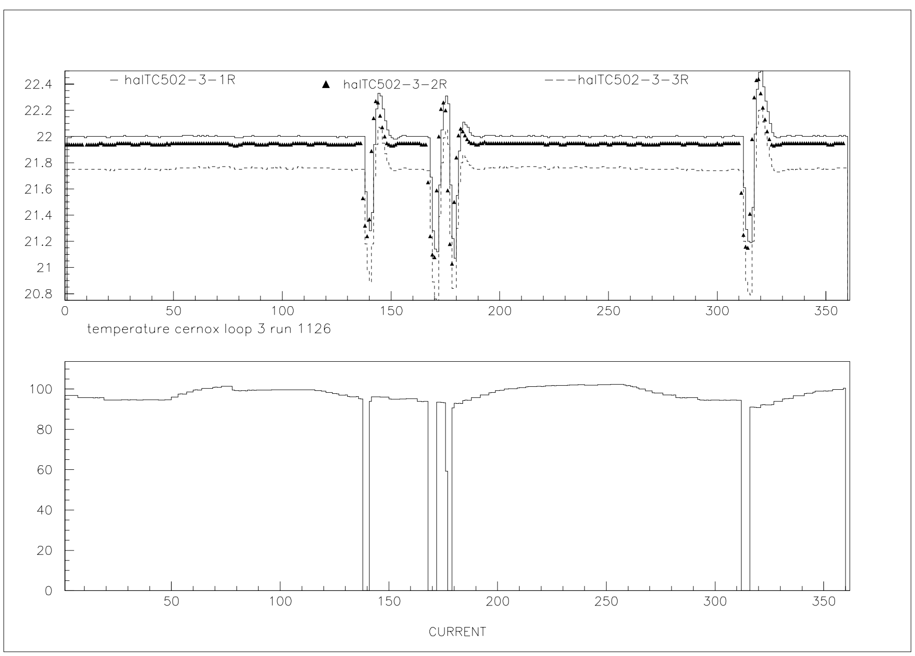

Fig. 4c. The temperatures of the three cernox CTI 119, CTI 118 and CTI 115

and the current versus time for run 1126.

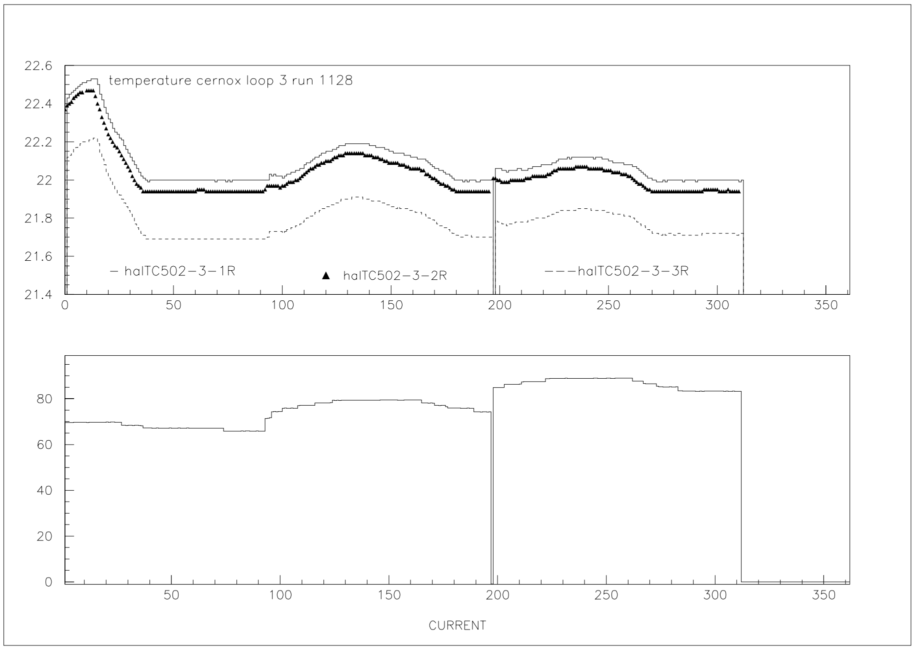

Fig. 4d. The temperatures of the three cernox CTI 119, CTI 118 and CTI 115 and the current versus time for run 1128.

We take the average temperature of CTI118 and CTI119 as the temperature downstream the cell. This implies the two sensors CTI118 and CTI119 have an offset of 0.025 K and -0.025 respectively. Fig. 4e, 4f and 4g show the temperatures of the three cernoxs CTI118 CTI 119 and CTI115 for the three runs shifted by 0.025, -0.025 and 0.375.

Cernox	offset
CTI118	0.025
CTI119	-0.025
CTI115	0.375

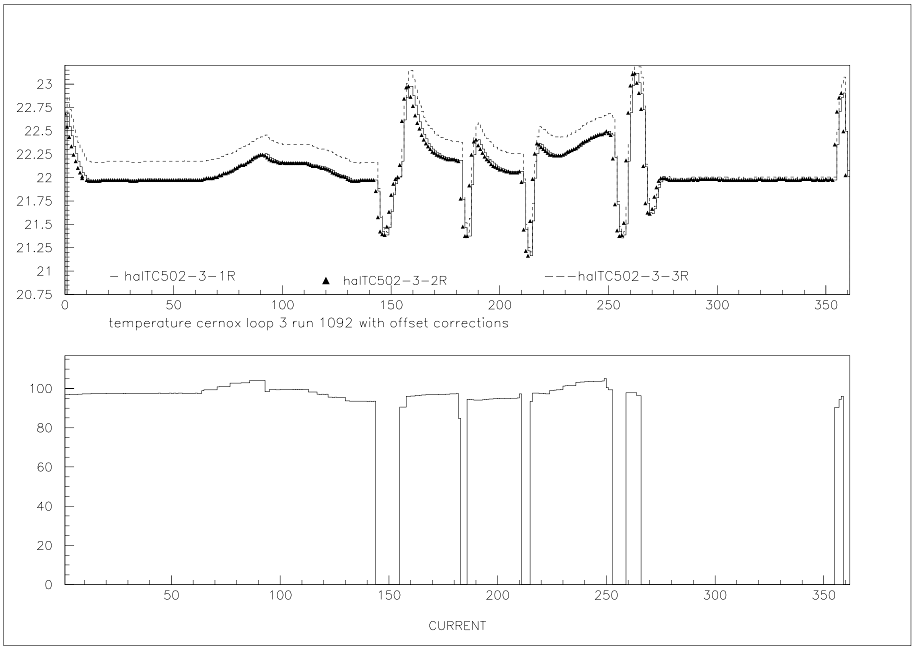

Fig. 4e. The temperatures of the three cernox CTI 119, CTI 118 and CTI 115 after offset corrections and the current versus time for run 1092.

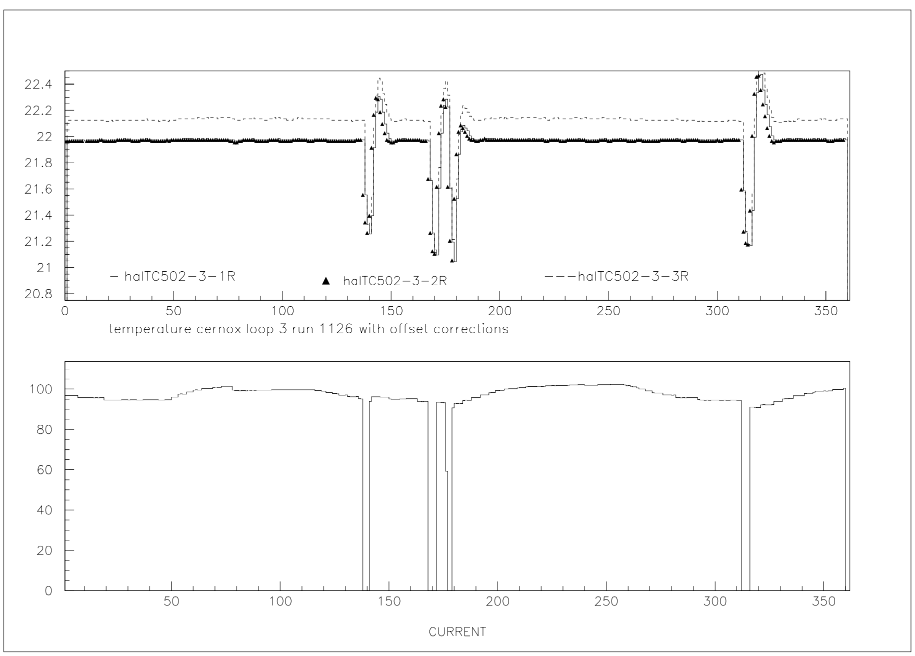

Fig. 4f. The temperatures of the three cernox CTI 119, CTI 118 and CTI 115

after offset corrections and the current versus time for run 1126.

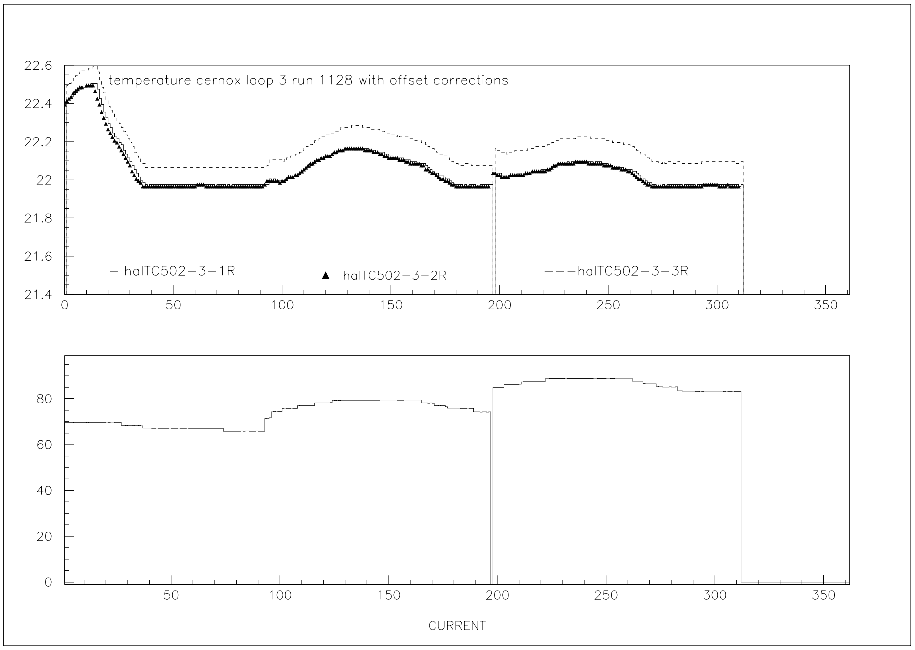

Fig. 4g. The temperatures of the three cernox CTI 119, CTI 118 and CTI 115 after offset corrections and the current versus time for run 1128.

Fig. 4h, 4i and 4j give the temperatures of the three sensors divided by the temperature at the cell. The decrease of the ratio between the downstream CTI119 and CTI118 sensors and the temperature at the cell is chekced for the three runs. The increase of the ratio of the upstream CTI115 sensor is checked as well. The heat load effect due to the beam current at 97 μA can only be seen on run 1092 because we have no long enough periods of beam down during the two other runs. We find ΔT = 0.0758$\times$2 (see paragrapher 3.2.2 for the $\times$2) that is

ΔT = 0.1516.

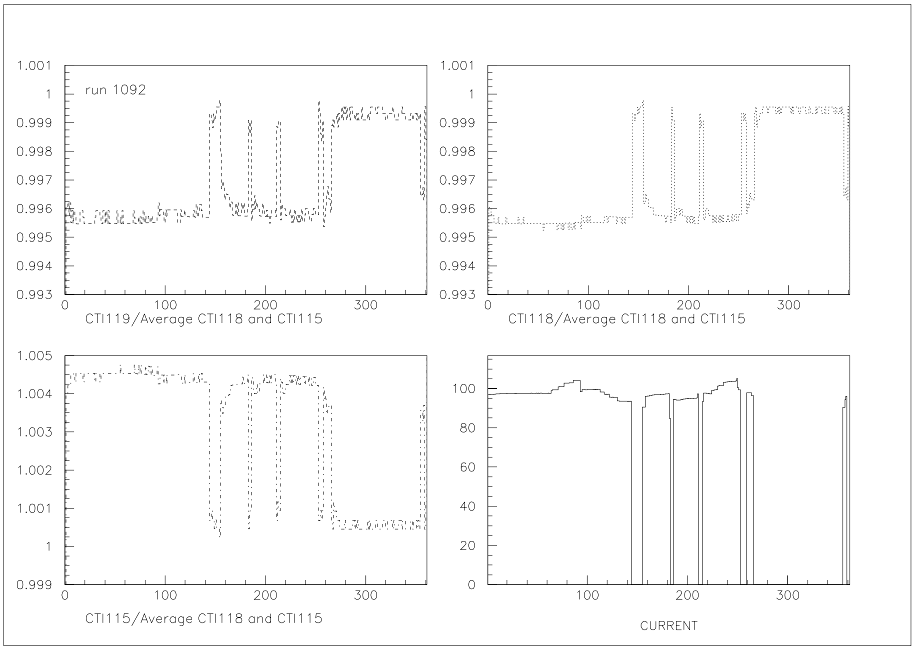

Fig. 4h. Temperature of the three cernox divided by the cell temperature and current versus time for run 1092.

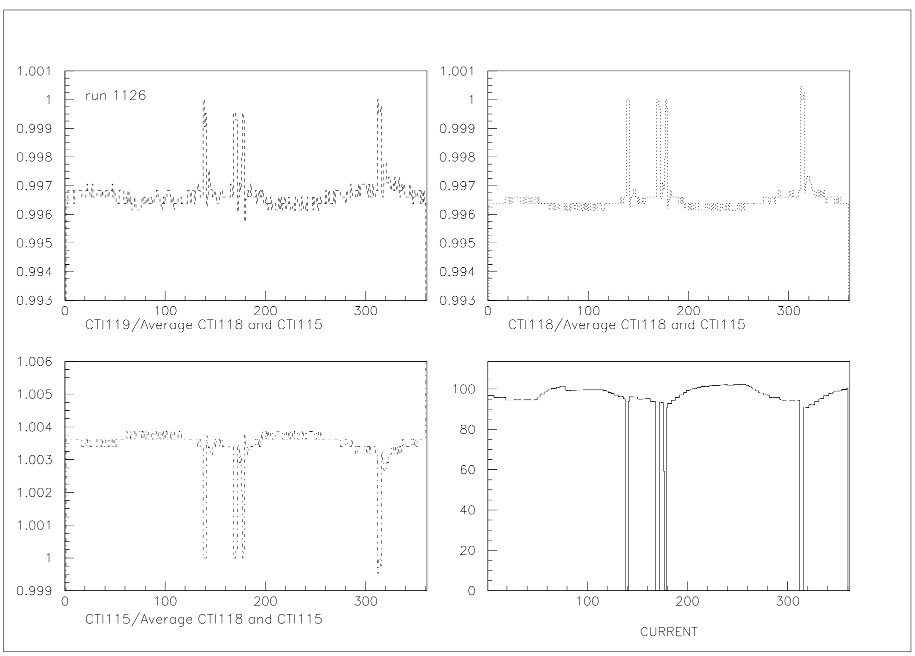

Fig. 4i. Temperature of the three cernox divided by the cell temperature and

current versus time for run 1128.

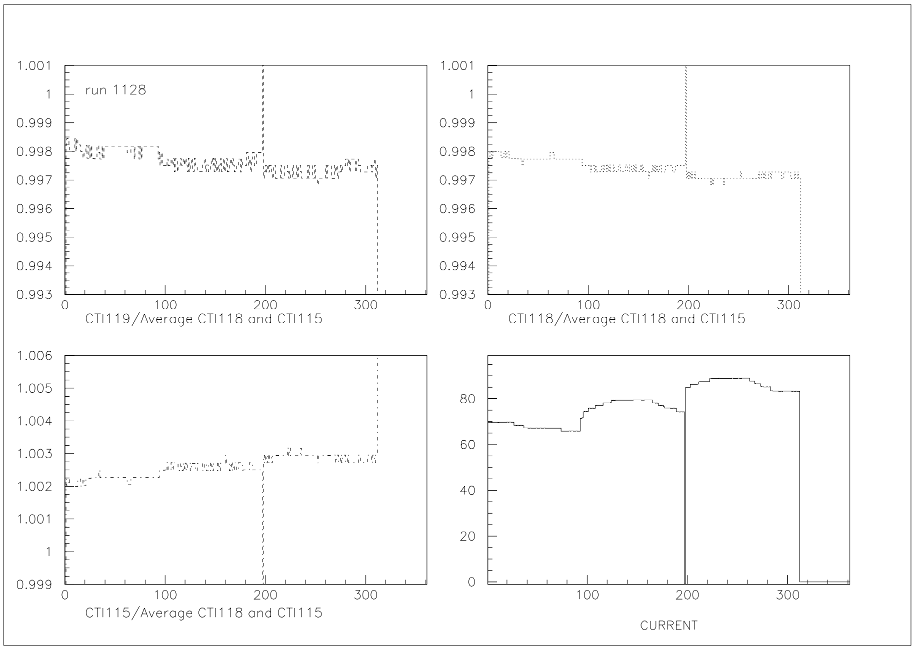

Fig. 4j. Temperature of the three cernox divided by the cell temperature and current versus time for run 1128.

Fig. 4k, 4l and 4m show the average temperatures of the cernoxs CTI118 and CTI115, corrected from the offsets, for the runs 1092, 1126 and 1128. They are the temperatures assumed at the cell.

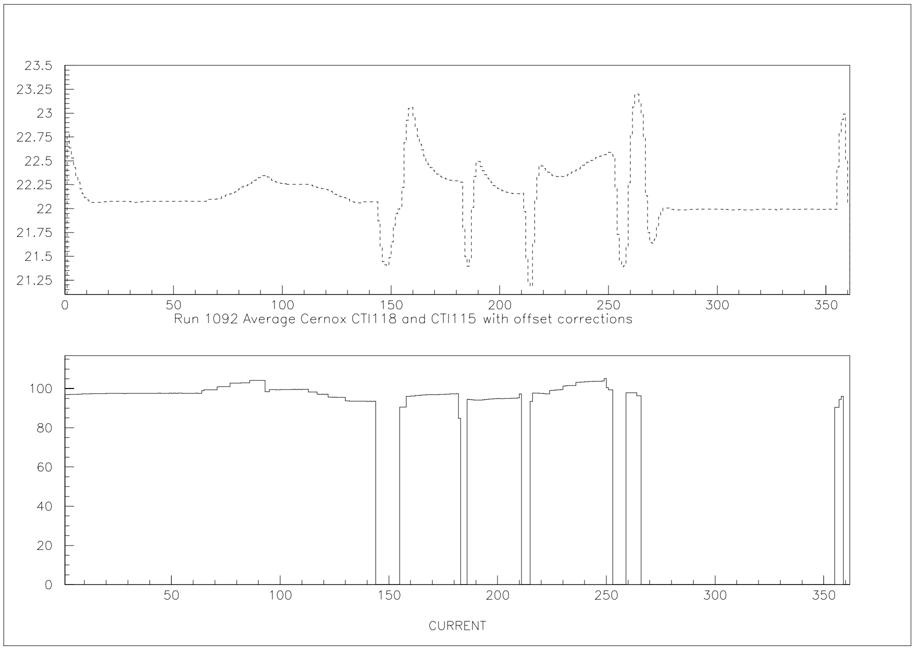

Fig. 4k. Cell temperature versus time after offset corrections for run 1092.

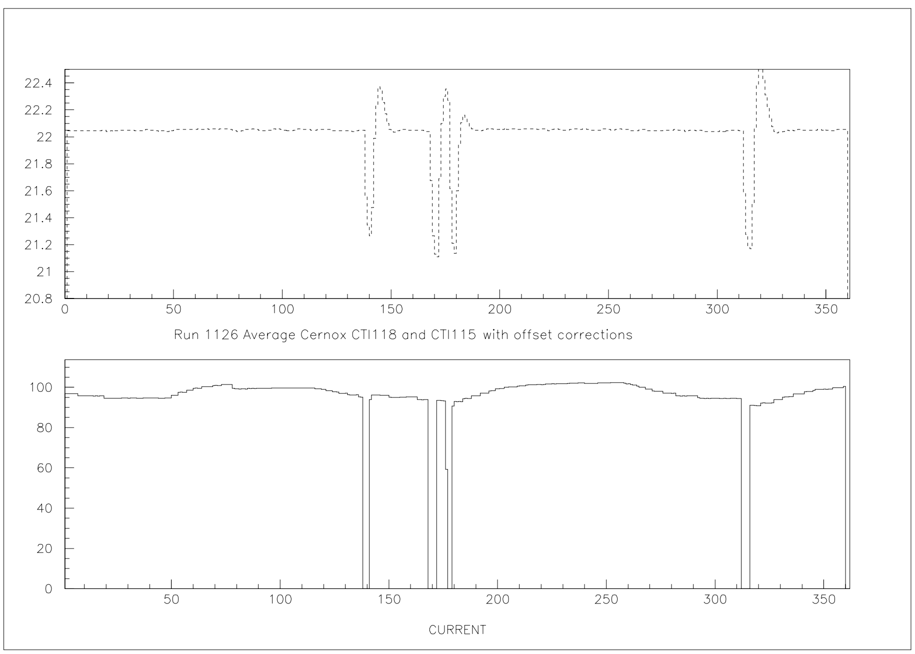

Fig. 4l. Cell temperature versus time after offset corrections for run 1126.

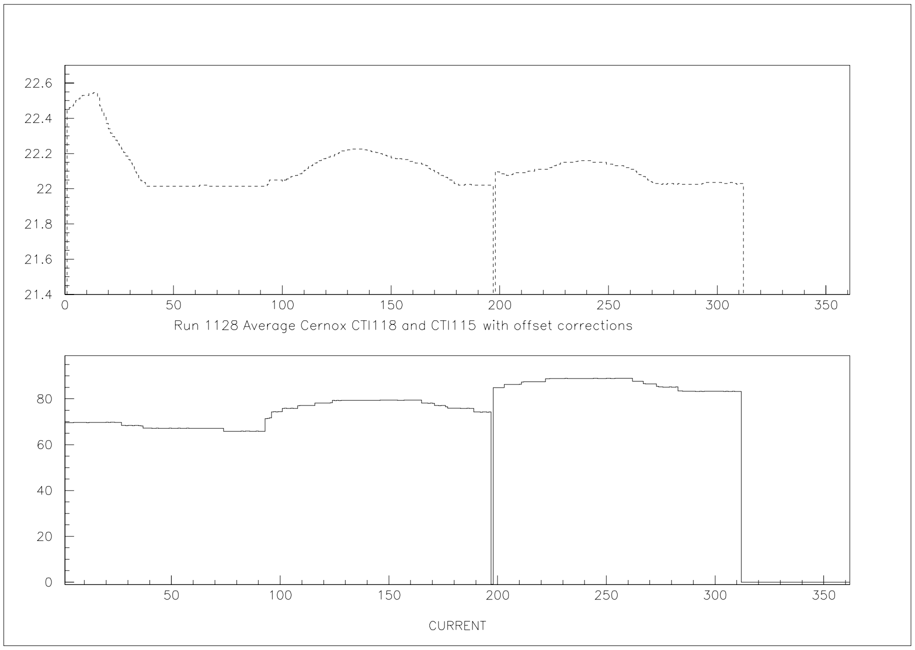

Fig. 4m. Cell temperature versus time after offset corrections for run 1128.

9.2.2 Error on temperature

The table below sums up the different errors and offsets for loop 2.

run	beam effect	s	R	offset ITC118	offset ITC119	offset ITC115
1092	...	0.0002	0.05	0.025	-0.025	0.375
1126	0.0758	0.0002	0.05	0.025	-0.025	0.375
1128	...	0.0002	0.05	0.025	-0.025	0.375
average	0.0758	0.0002	0.05	0.025	-0.025	0.375

... means the run does not allow to see the beam effect.

9.2.3 The other temperature sensors

The figures 4o,4p and4q show the data of the five other loop 3 temperature sensors respectively for runs 1092, 1126 and 1128. The top left plot corresponds to the cernox sensor CTI116, the top right plot is the diod sensor DTI88, the middle left plot is for the diod sensor DTI89, the middle right the Allen Bradley sensor ATI177, the bottom left is for ATI121 and the last plot is the current

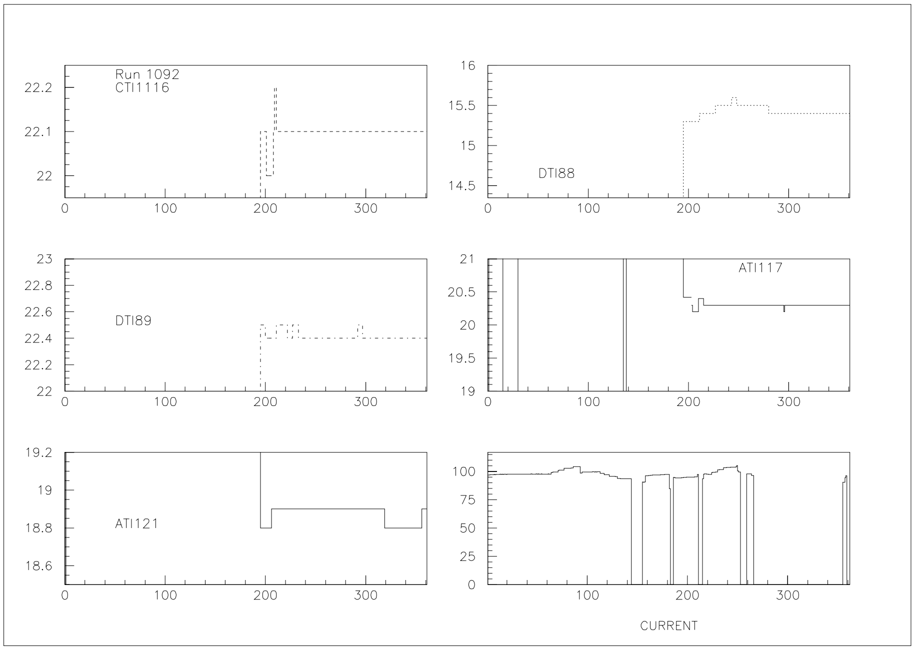

Fig. 4o. CTI16, DTI88, DTI87, ATI117 and ATI100 temperature data and current versus time for the run 1092.

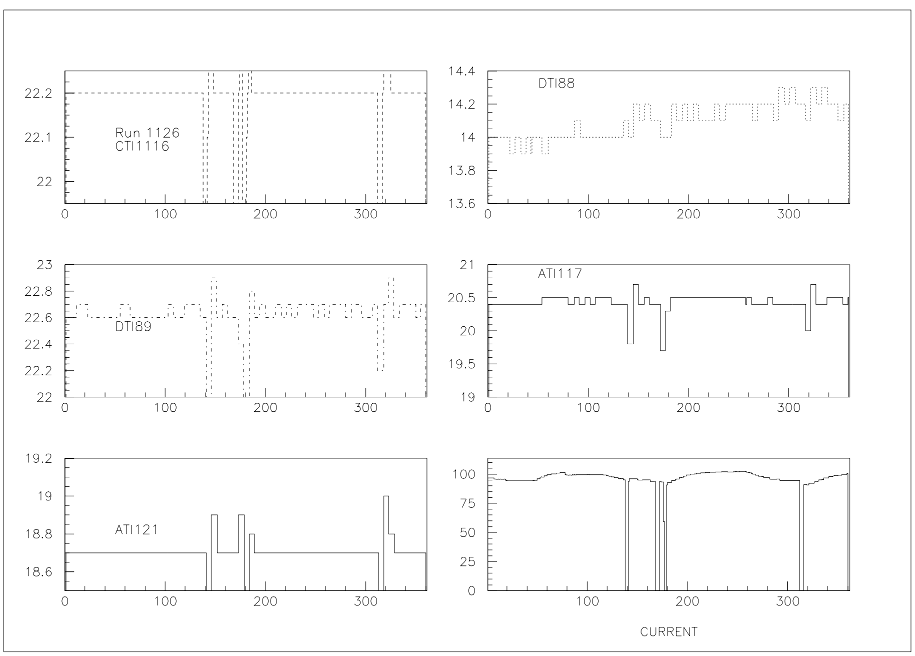

Fig. 4p. CTI16, DTI88, DTI87, ATI117 and ATI100 temperature data and

current versus time for the run 1126.

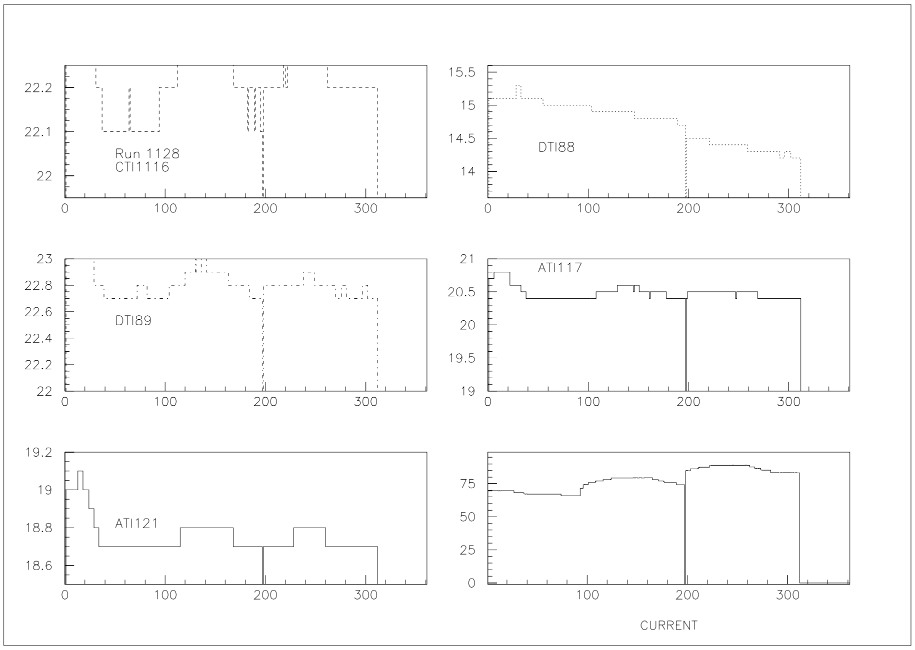

Fig. 4q. CTI16, DTI88, DTI87, ATI117 and ATI100 temperature data and current versus time for the run 1128.

As in the loop 2 the change of the sensors are consistent with their locations. In the begining of the run 1092, the data are not recorded.

As the change of current is higher (about 100 μA) we can see easily in runs 1126 and 1128 the correlation between a current change and the variation of temperature. All the sensors (but DTI88) seem to follow the increase of current. This is consistent for all the sensor of the loop since the cryogen is warmer. DTI89 wich measures the temperature of the outgoing coolent helium should be also warmer. DTI88 wich measures the temperature of the entering coolent deacreases with apparently no correlation with the beam variations. This can be understood *via* the Joule-Thomson effect that occures for non-perfect fluids: Since the temperaure increases, the target operator should have opened the Joule -Thomson valves wider. Since we are below the inversion Joule-Thomson curve, the effect is a decrease of the coolent fluid temperature at the crossing of the valve. This also explains the steps in the temperature curve for run 1128. they correspond to each time the target operator has opened the valve wider.

The figure 4r shows the ratio of the temperatures with the temperature at the cell for run 1128. As for loop 2, the variations of the temperatures are consistent with the position of the sensors.

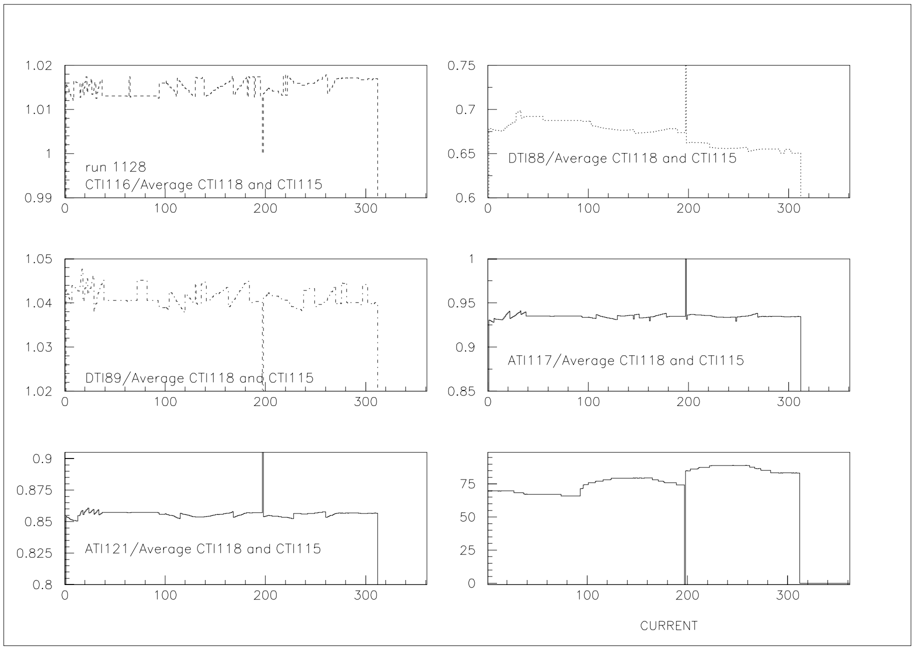

Fig. 4r. CTI16, DTI88, DTI87, ATI117 and ATI100 temperature data divided by the temperature at the cell and current versus time for the run 1128.

10 Annex B. Pressure Analysis

10.1 Loop One

No data are available yet for the first loop.

10.2 Loop Two

The two VPTs of loop two are VPT74BT103, situated near the heat exchanger and VPT74BT109 situated near the cell. The pressure is given by PT128 at the entrance of the loop and PT131 at the exit. The figures 6a, 6b, 6c and 6d give the temperatures and the pressures for the runs 1722, 1728, 6683 and 6721 of the HAPPEX experiment dress rehearsal (december 17-24, 1997)

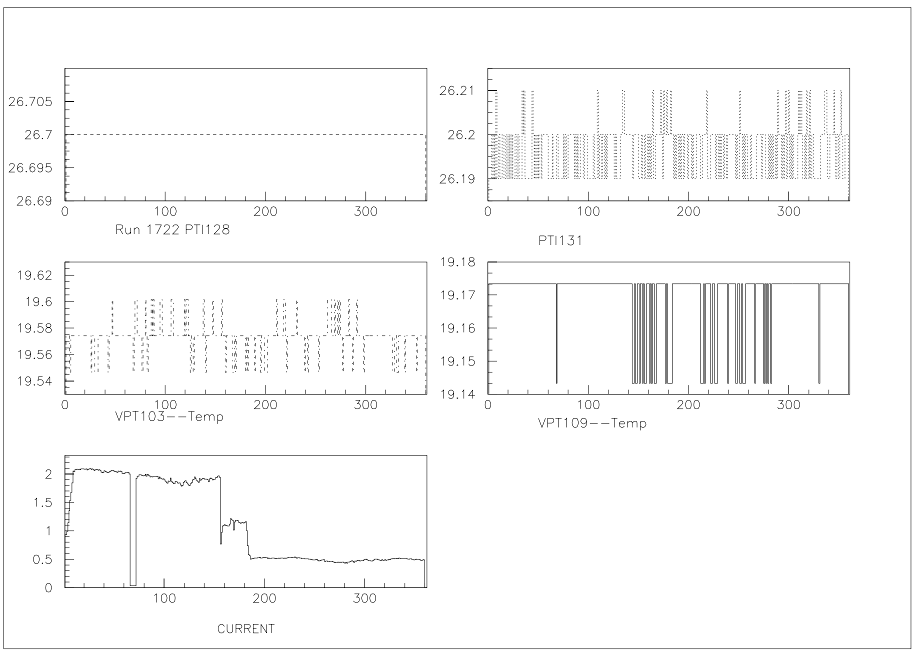

Fig. 6a. VPT103 and VPT 109 temperatures, PTI131 and PTI128 pressures and current versus time for run 1722. The units are Kelvin, PSIA and microAmpere.

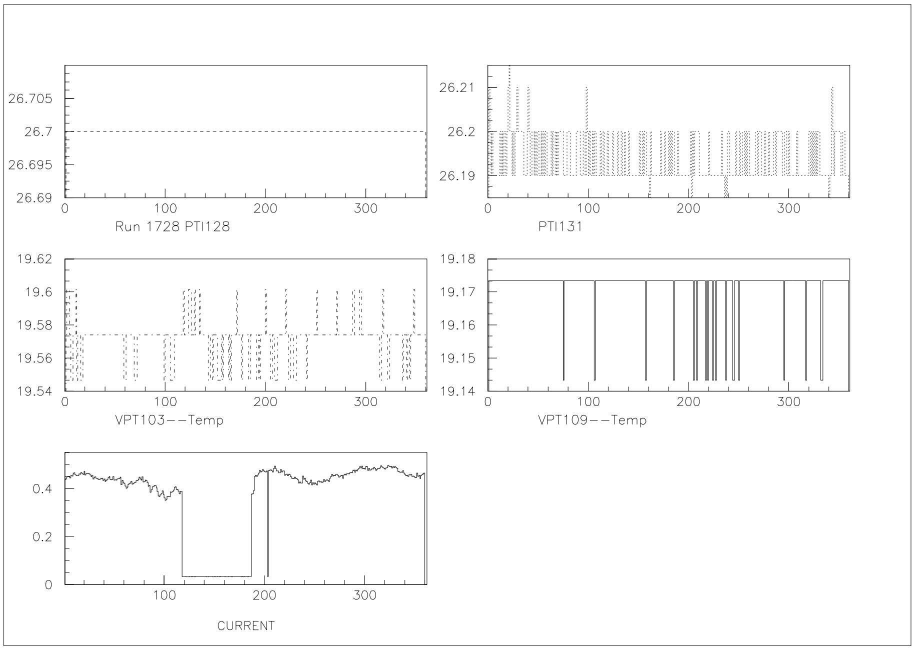

Fig. 6b. *VPT103 and VPT 109 temperatures, PTI131 and PTI128 pressures and current versus time for run 1728.*

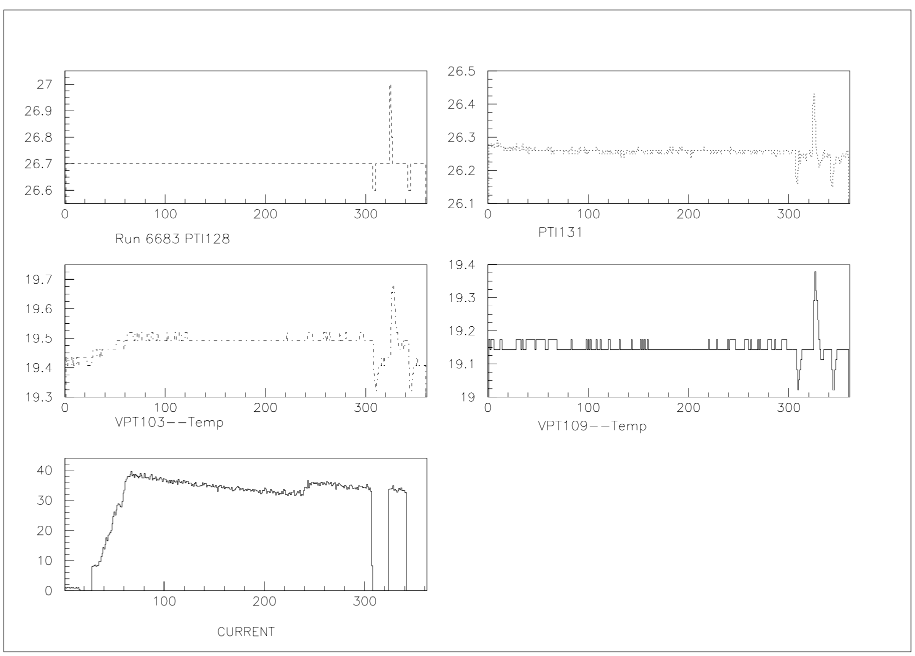

Fig. 6c. VPT103 and VPT 109 temperatures, PTI131 and PTI128 pressures

and current versus time for run 6683.

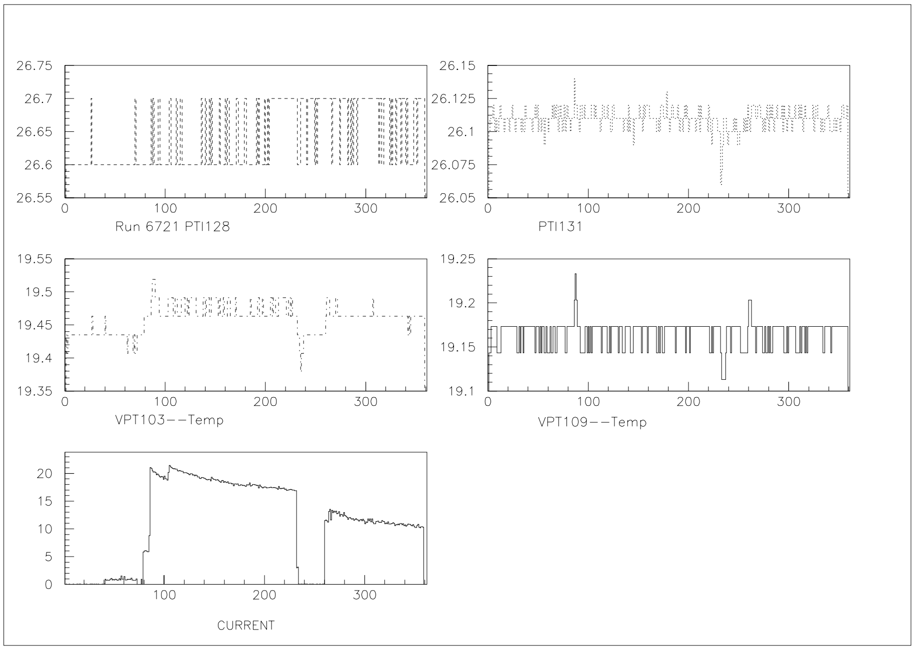

Fig. 6d. *VPT103 and VPT 109 temperatures, PTI131 and PTI128 pressures and current versus time for run 6721.*

For the two first runs, VPT109 should indicate a temperature of 19.00 K, that is the average of the sensors CTI107 and CTI104 (see paragraph 3). That means we have an offset of 0 .173 K for VPT109 and 0.5675 for VPT103. The current was of a few μA. In addition for this runs, the 4 cm cell was used thus the heat load is very small and we cannot see the correlation between the current changes and the pressure and temperature variations.

The pressures are also in the expected range (26.7 PSIA for PTI1128 and 26.2 for PTI131).

The figures 6c and 6d give the temperatures and pressures for runs at 40 and 20 μA that allow to see the effect of the current. The 15 cm cell was used. We see as in the previous paragraphers the correlation between the current change, the pressure and temperature variation. The directions of these variations are consistent with the directions of the current change.

The offset for VPT109 is of 0.173 K . For VPT103 the offset is 0.435 K.

We can see the incertainty on the lecture (relative error) of the sensor *via* the numerous steps of equal height that appear even if the current is stable. The step height is the relative error. For the pressure sensors PTI128 and PTI131 the relative error on the lecture is of 0.1 PSIA . The temperature sensor VPT103 has an relative error of 0.06 K and VPT109 has an error of 0.3 K.

10.2.1 Comparison between the cernox CTI105, CTI108, CTI109 and the VPTs.

The figures 6e, 6f, 6g and 6h give the plots of the three cernox temperatures and the current for the runs 1722, 1228, 6683 and 6728 respectively. As previously the current for the two first runs is not high enough to allow to see the correlation between the temperature and the current. Nevertheless it allows to check the offset of the cernox sensors. We see the 0.02 K offset of the sensor ICT 108. This is consistent with the data of paragrapher 3. For the two last plots the current is high enough and one can see the correlation between the temperature and the current. For these two runs, the sensor ITC108 is noisy.

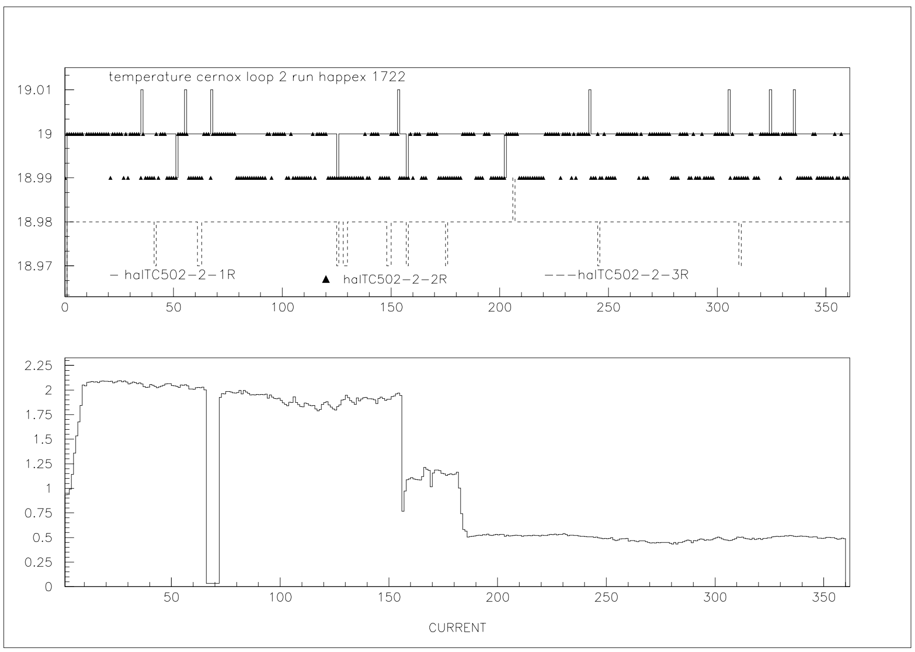

Fig. 6e. Cernox temperatures and current versus time for the run 1722.

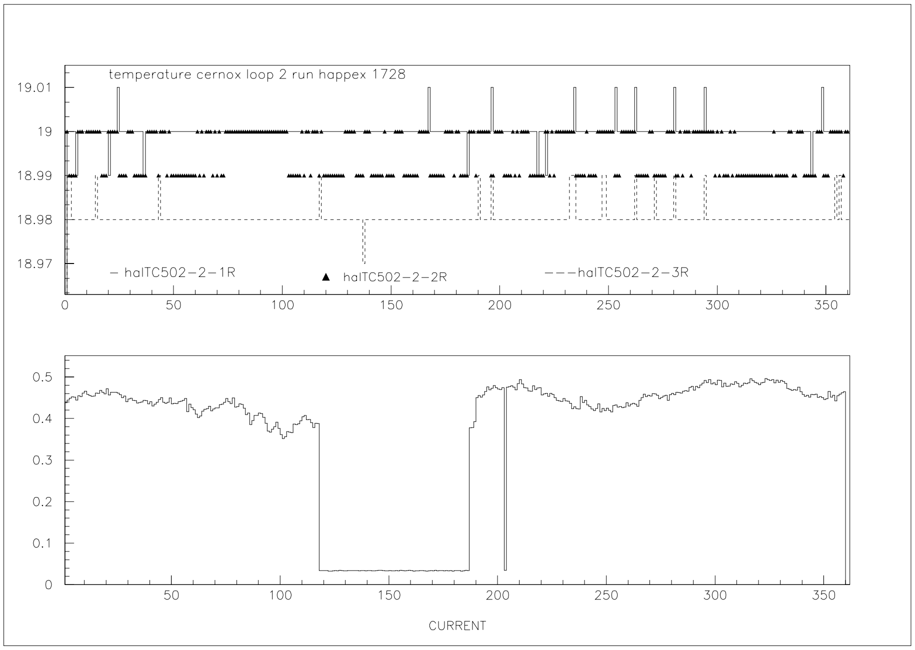

Fig. 6f. Cernox temperatures and current versus time for the run 1728.

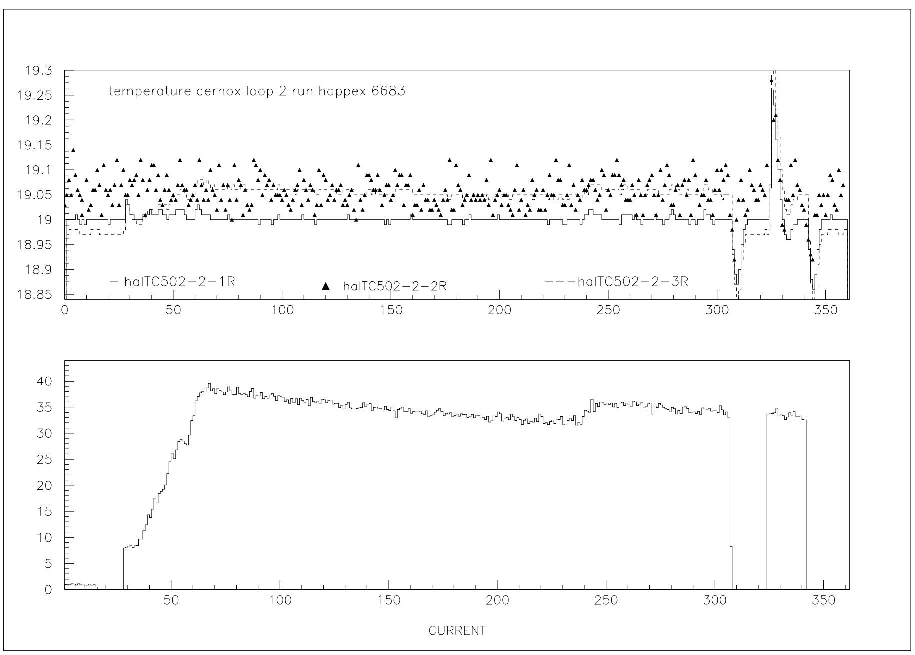

Fig. 6g. Cernox temperatures and current versus time for the run 6683. ITC107 is noisy.

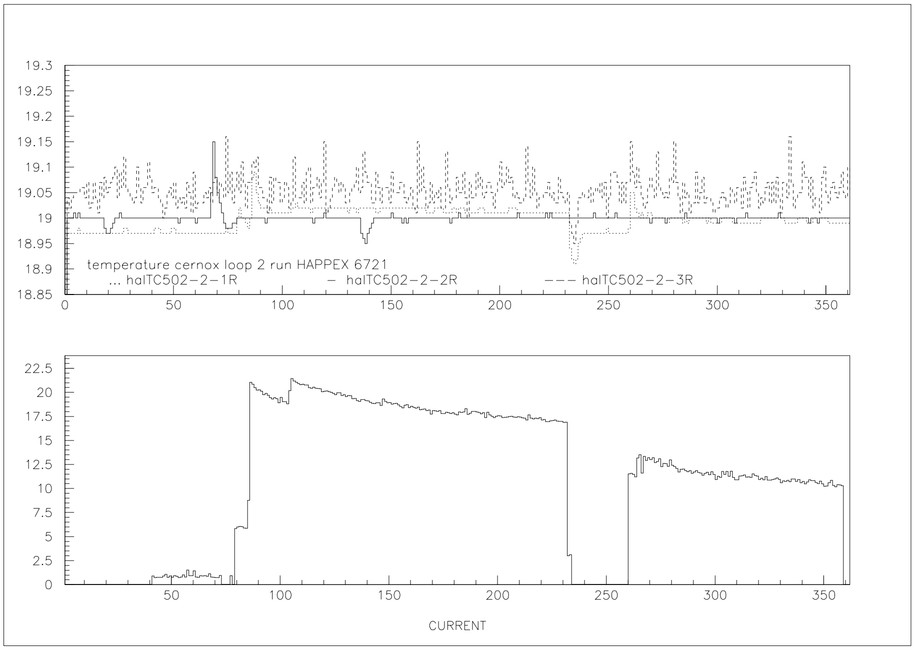

Fig. 6h. Cernox temperatures and current versus time for the run 6721. ITC107 is noisy.

The figures 6i, 6j, 6k and 6l show the temperature at the cell and the ratio between VPT temperatures and cell temperature. As the heat load effect is not visible in the two first runs, we can check the offset of the VPTs with figures 6i and 6j. We find for VPT103 a relative offset of +0.0308 that is an offset of 0.585 K. For VPT109 the relative offset is 0.0096 that is an offset of 0.182 K.

The two last figures allow to check if the variation of the ratio between VPT and the cell temperature is consistent with the location of the VPTs during a variation of beam current.

The two VPTs are situated before the cell and one sees an increase of temperature when the current goes down. this is what we have expected since the power heaters load heat when the current decreases. At the contrary the cell temperature decreases obviously with the beam current.

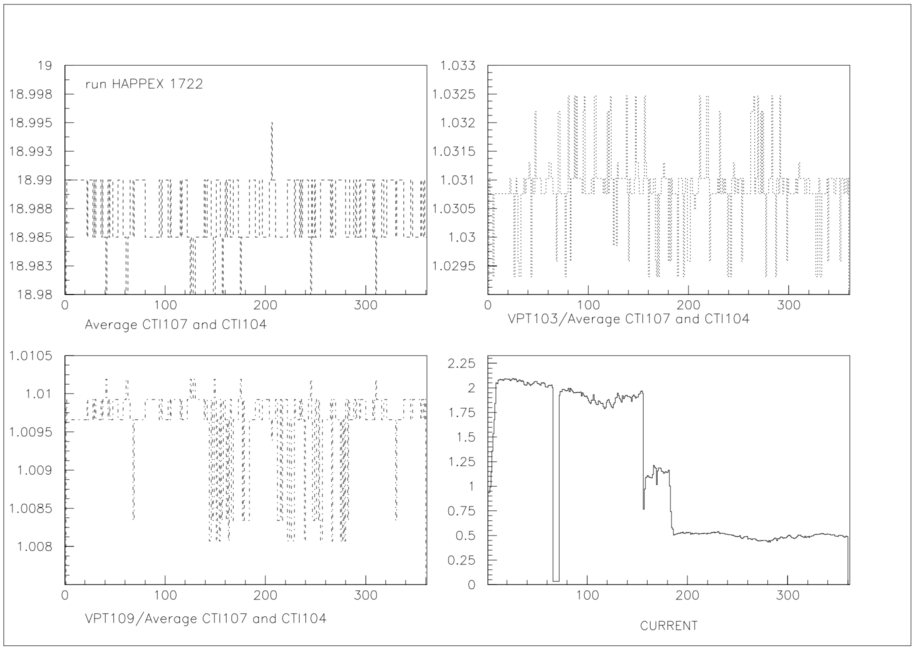

Fig. 6i. Cernox temperatures divided by the cell temperature and current versus time for the run 1722.

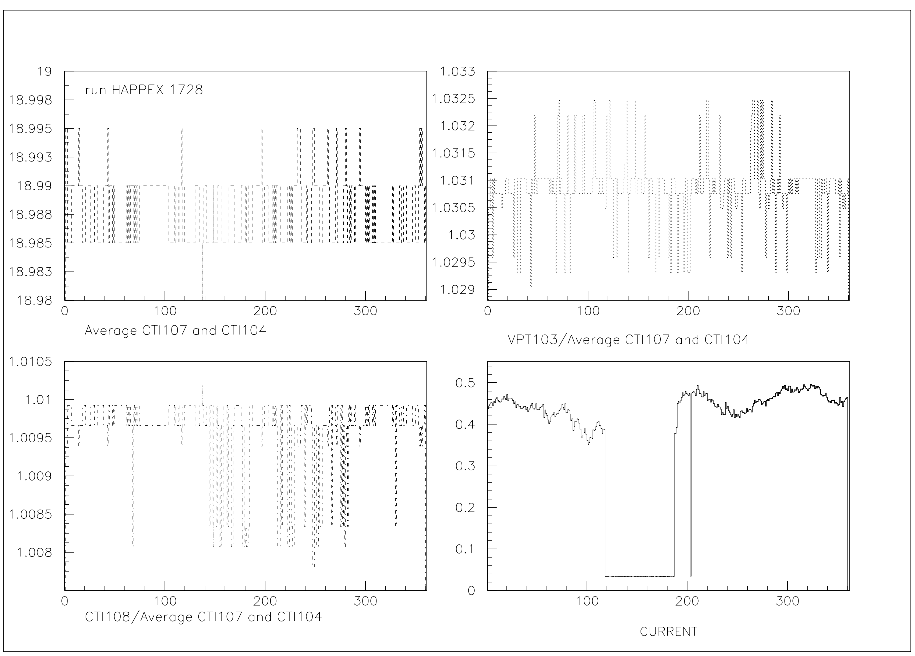

Fig. 6j. Cernox temperatures divided by the cell temperature and current

versus time for the run 1728

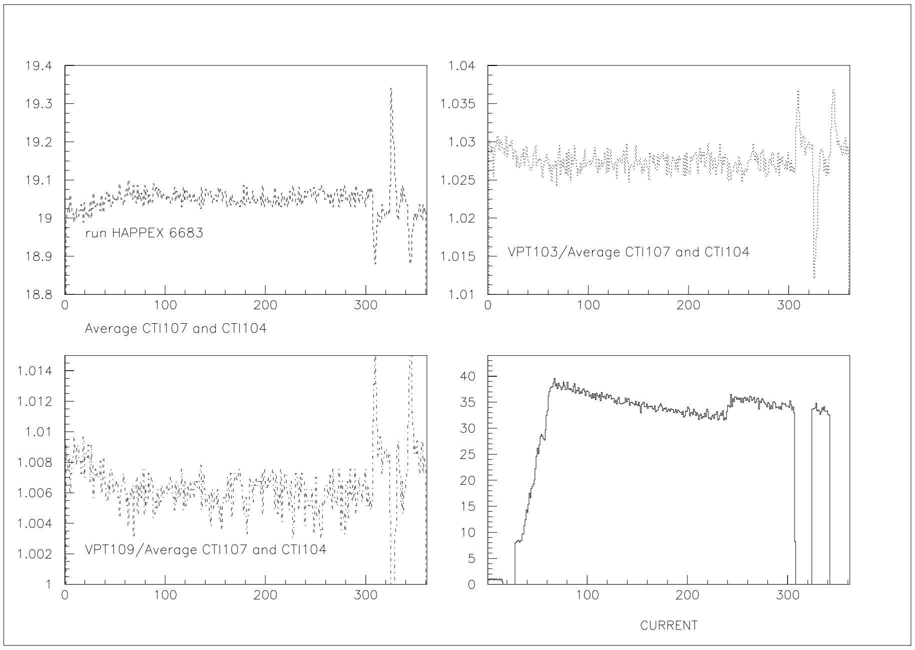

Fig. 6k. Cernox temperatures divided by the cell temperature and current versus time for the run 6683.

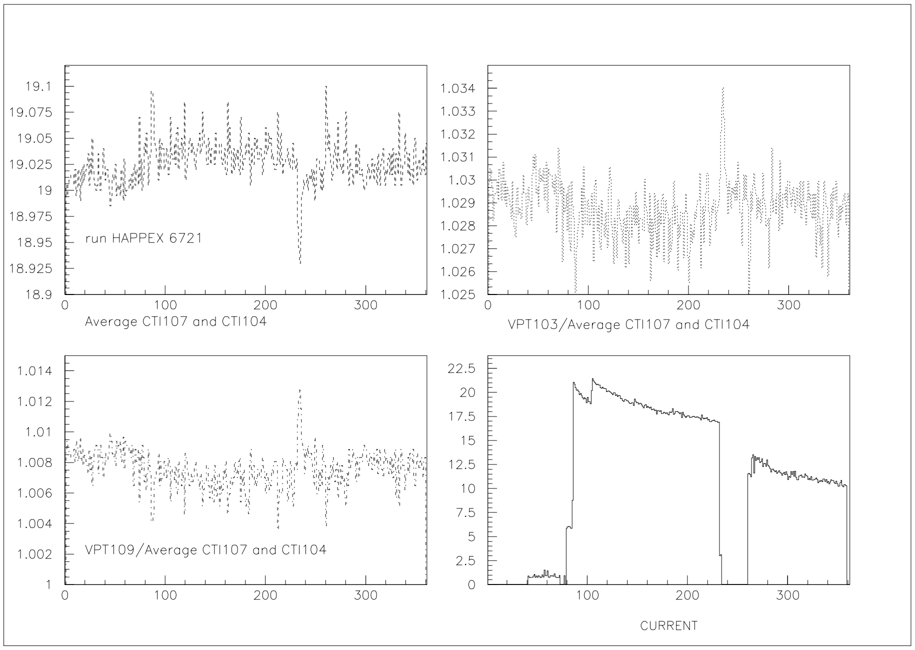

Fig. 6l. Cernox temperatures divided by the cell temperature and current versus time for the run 6721.

10.3 Loop three

No data are available for loop three