

UCI KCCAMS Facility

AMS Settings to ^{14}C measurements

January 22, 2009

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I. General information

The KCCAMS facility operates a 500 kV compact AMS unit from National Electrostatics Corporation (NEC 0.5MV 1.5SDH-2) (Southon, 2003a).

The AMS system is very small and robust and has a complex set of hard and software interlocks to provide safety operation for the user and the system itself. However, it is still a complex system which can be damaged by improper operation, particular if interlocks are bypassed. To avoid that, the operator should be able to recognize the main features of the system and have a feel for normal operation during a run.

This protocol was written to help you on these tasks. There is more than one way to tune an AMS system, some of the procedures presented here can probably be performed in different order. For any further questions contact J. Southon or G. dos Santos.

II. AMS Particle Accelerator principles

The compact AMS system main features:

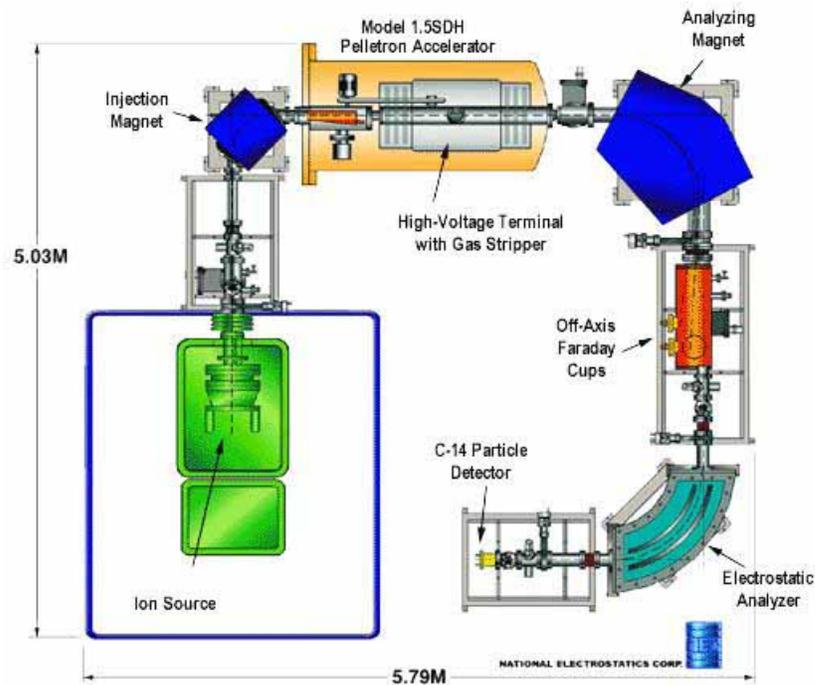


Fig. 1 The NEC AMS 0.5MV 1.5SDH-2 unit.

The AMS system is equipped with the NEC 40-sample MC-SNICS Cs sputter ion source. The negative ion beams produced by the ion source are injected into the accelerator tank using a bunched 90° double-focusing magnet system (injection magnet) to select the appropriate mass. The fast beam switching (bouncer), for sequential measurement of ^{14}C and the stable isotopes ^{13}C and ^{12}C , is performed by varying the bias voltage on the insulated injection magnet vacuum box.

The accelerator terminal contains a high density recirculating gas stripper (2microgram/sq cm of argon), with two turbo pumps for maintaining the best possible vacuum in the accelerator tube. The accelerator tank is filled with high-pressure (80psi) SF₆ for isolation of the high voltage terminal. For maintenance the tank is rolled sideways after the SF₆ is pumped out and the entire acceleration column is withdrawn from the tank.

The high energy analysis system consists of a 90° double-focusing analyzing magnet (HE BM) and a 90° electrostatic spherical analyzer (ESA), which perform an achromatic beam transport of the ¹⁴C particles to the detector. The effects of small beam energy variations on beam position cancel in the two elements, leaving the beam centered to the detector. A silicon solid state ionization detector at the end of the beam line measures particle energies to distinguish ¹⁴C from noise.

The measurement of the stable carbon isotopes is performed in the Faraday cup chamber (off-axis Faraday cups) after the high energy 90° magnet.

The control and data acquisition systems supplied with the instrument are PC-based and use standard nuclear physics and laboratory automation hardware. The system is equipped with beam diagnostics (Faraday cups and beam scanners) to aid in tuning stable isotope beams. Final tuning is carried out by systematically varying critical power supplies to peak up the ¹⁴C count rate under computer control. In the unlikely event of malfunction or cooling system failure, the AMS system is programmed to shut down.

III. Accelerator NTwork control system (AccelNET).

AccelNet is a software package for control of electrostatic particle accelerator systems (Kitchen 2001a,b). The AMS system runs under control of an AccelNet package that provides a complete data collection system capable of managing the data collection event by event as well as machine operation. AccelNet runs on PC hardware under Linux.

The AMS control workstation or console consists of a computer and assignable meter/knobs system (fig. 2). The control workstation also operates beam monitoring devices to establish the shape and intensity of the ion beams.



Fig. 2 The accelerator control workstation or console.



Fig. 3 The first main window of the Accelnet control System.

The accelerator startup windows and procedures are already arranged in a way that hopefully provides an organized and convenient method to starting up the machine. They are divided on two main windows (fig. 3 and 4). By convenience, each window covers two computer screens at the control workstation. The user can pass from one screen to the other moving the mouse from left to right and vice-versa.

The first main window (fig.3) contents:

- Main AccelNet controller bottoms and Beam Line Diagrammatic Display that shows the accelerator layout represented by symbols and icons (see section VI);
- Pen_recorder that displays parameters of the accelerator, to be monitored by the user (the operator will find some of the parameters already selected);
- AMS tools window that shows a several of commands to be used during the setting of the machine;
- Meters and knobs restore window that shows recorded groups of settings of the assignable meter/knobs. Each group restores a particular set of parameters of the machine that can be seeing and tuned by the knobs (for example, g1 restores the parameters related with ions source and ¹⁴C corrective steerers, etc);
- Beam Profile Monitor (BPM) setup allows the user to monitor the shape of the beam current before and after the tank accelerator. This AMS unit has 4 BPM's that together with the Faraday Cups complete the beam diagnostics set of the machine;
- SNICS Ion source window shows the parameters to warm up and run the ion-source (section IV).



Fig. 4 The second main window of the Accelnet control System.

The second main window display the data acquisition system software supplied with the instrument. Using the three small windows displayed, final tuning can be carried out by systematically varying critical power supplies to maximize ^{12}C and ^{13}C beam currents at the Faraday cups placed off-axis (HE MFC 1 and HE MFC 2, respectively) and to peak up the ^{14}C count rate at the solid state detector.

The second main window (fig.4) contents from left to right:

- HISTmng window with a gate window displayed. Inside this gate window the user will see the ^{14}C particles detected by the silicon solid state detector (section VI -fig. 25). The gate lines (Xgatemax and Xgatemin) were defined, using a modern standard sample (oxalic acid I \rightarrow OX-I) to establish the right area where a clear peak of the radiocarbon can be visible (section VI - fig. 26);
- DMANmng window with a runlist already loaded. This window is set up by the user to inform the computer control system how the samples will be run (time, number of counts expected, etc). It also allows the user to see the final results during measurement (section IV.2 - fig. 14);
- Dosimetry operation window displays the $^{13}\text{C}/^{12}\text{C}$, $^{14}\text{C}/^{12}\text{C}$ and $^{14}\text{C}/^{13}\text{C}$ ratios in real time, based on the stable beam currents and ^{14}C particles accumulated at the detector (section V.3 - fig 24). At this window, the user can also monitor the beam current intensities of ^{12}C and ^{13}C measured in the off-axis Faraday cups at the Faraday cup chamber.

IV. Icon and alphanumeric legend and display colors of the AccelNet Control window

Before the user sets up the system, he/she should be familiar with how the information is provided at the AccelNet Control window. There are three indicators: a) icon - a picture of a device, b) alphanumeric - parameter name value and units, and c) display color in icons or alphanumeric parameter - shows status.

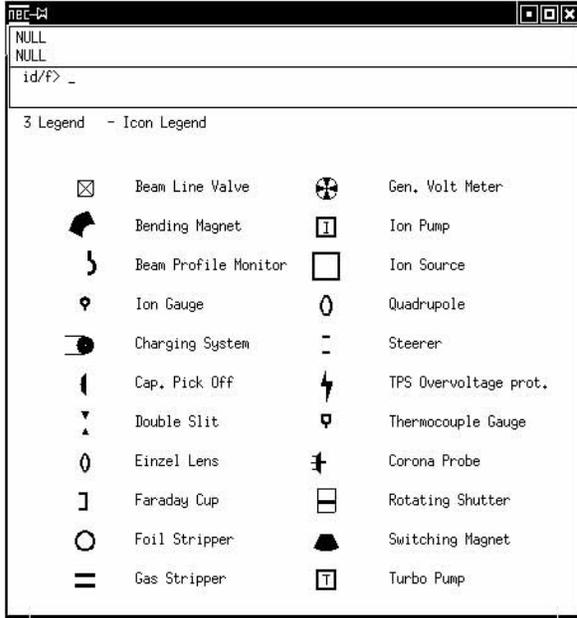


Fig.5 Icon legend

Alphanumeric legend commonly used:

- S1 → SNICS ion source;
- BLV → Beam Line Valve (fig.5);
- LE → Low Energy;
- HE → High Energy;
- BPM → Beam Profile Monitor (fig.5);
- FC → Faraday Cup (fig.5);
- MFC → Faraday Cup off the main trajectory;
- ES → Electrostatic Steerer (ESX - to correct beam position in X direction, ESY - to correct beam position in Y direction);
- MS → Magnetic Steerer (MSY - deflect beam current in Y direction);
- BM → Bending Magnet (LE BM - injection magnet, HE BM - analyzing magnet);
- MBS → Beam jumping control electronics;
- TPS → Terminal Potential Stabilizer;
- ESA → Electrostatic Spherical Analyzer;

Display Colors:

Icons	Blue	→ device is inactive (power off)
	Green	→ device is active (power on)
	Red	→ Cage source is open and/or interlock is enable
	Yellow	→ has various meanings depending upon the icon (FC inserted, BM moving, maintenance, interlock is bypassed)
Alphanumeric	Green	→ value is "on" and within database defined limits
	Red	→ value is outside of database defined limits
	Violet	→ indicates a parameter status "off" and/or error". It also means a missing module.

Table 1. The meaning of display colors of the AccelNet Control window.

The small square solid boxes on fig.6 not cited on fig.5 are buttons which allow the user to change parameters corresponding to nearby symbols, or to turn devices on and off. For example, the boxes near the two magnets (BM's) turn the power supplies on and off. Some of these boxes hide more than one parameter value, that are display each time that the user hit the left bottom of the mouse. **CAREFUL do not hit the right bottom of the mouse!! Some of these square boxes hide "on" or "off" options that will be activated if you accidentally hit the wrong mouse button or click more times than you intended.**

V. Sample wheel insertion.

The user should place a wheel of up to 40 samples pressed in aluminum holders in the ion-source. Two documents should accompany the wheel:

a) an "AMS submittal sheet" with the following information: date, submitter, contacts, project name, sample description and any pertinent information related to the samples to be attached to the AMS SUBMITTAL SHEET BINDER, and

b) a "wheel sample list" (template is provided in AMS prep-lab) with the sequence of cathode positions and UCI sample lab numbers to be attached to the run-book at the day of the respective measurement.

V. 1. Getting ready to change wheels (or crash the cage):

```

localhost AccelNET - Accelerator Network Control System <3>
S1 ITX PurSR off
S1 ITX PurSC off
id/f> _

10 Src1 - SNICS Ion Source 1
S1 INJ flow flow open on
S1 ITX off
S1 CAT -6,71 KV -0,18 mA
S1 CSF -3,16 KV -1,60 mA
S1 EXT 14,29 KV 2,63 mA
S1 FOC -1,03 KV -0,48 mA
S1 HVS -1,2 KV -0,05 mA off
S1 ION 24,1 A 7,5 V
S1 MCS 0 rest home Remote
S1 OVN 1 0,00 V 133,0 C
S1 OVN 2 45,40 A
LE FC -1,00e-10 A in
LE BLV closed
LE IGC 1 1,3e-08 T EmissOn
LE MSY -0,011 A on
LE CP 1,0e-04 T
LE BH 83,405 A 0,1 G nop IICon
LE HPB 4226,4 G 1,2 T
LE IGC 2 2,1e-07 T EmissOn
LE TP 1 off/prot open open
S1 INJ TotInjV 22,2 KV
  
```

At the SNICS Ion source window at the console (fig. 6),

- HVS (High Voltage Supply) → off
 - S1ITX (isolator transformer) → off
- Screen should look dark blue

S1 Alphanumeric legend (fig.6):

CAT → Cathode (wheel);
 CSF → Cesium Focus;
 EXT → Extractor;
 FOC → Enzel Lens;
 HVS → High Voltage Supply;
 ION → Ionizer;
 MCS → multicathode (sample position);
 OVN1 → Cesium reservoir.

Fig. 6 SNICS S1 window at the Accelnet Control System (inverted background color- parameters "off" are in light green color).

The three first lines (fig.6) are the command lines → they display the parameter value applied and respective read-back. At the prompt, the user can change any parameter value by typing the appropriate command. For example, to change the ionizer from one value to the other go to the prompt at the third line and type "id/f>ch [value]" and press enter.

- All FC's should be in (cups in - turn yellow in fig. 7);
- Close LE BLV (valve closed - turns blue)
- Change the LE Steerers from normal (norm) to maintenance (maint). Left click on right square boxes before BLV (turns from green to yellow).
- Make sure the wheel is in position 0.
- Change the injection magnet MBS (at the LE side) from normal (norm) to maintenance (maint). Left click on left square box after BLV and magnet steerer (turns from green to yellow).
- Turn off the source (S1 ITX). This will automatically turn off S1 HVS – the source high voltage – as well.

7. Open the Ion Source cage and hang a ground hook on one of the side bars (fig. 8).

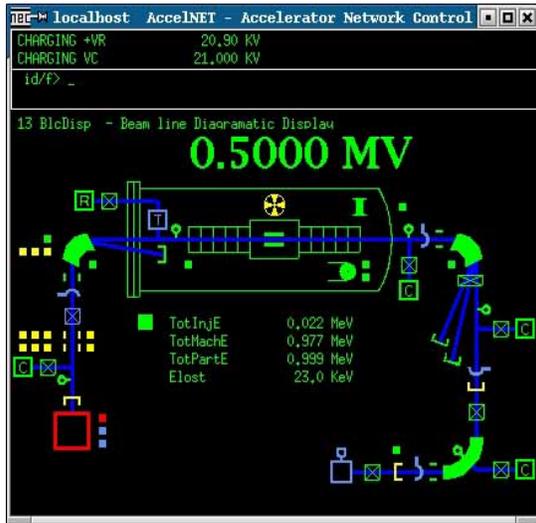


Fig. 7 Beam Line Diagrammatic Display

8. At the SNIC indexer controller panel, change the left hand switch from remote to local control (panel below cryogenic pump - fig.9).

9. Plug the indexer controller cable into the source controller power supply bellow the source (green LED lights up - fig. 10).

10. At the ion source controller power supply box bellow the source, retract the wheel (left hand switch - LED turns green to red).

11. At the controller box, close the gate valve to isolate the wheel from ion source body (right hand switch - LED turns green to red)

12. Bleed up the sample change with Ar from the bottle in the cage. Open the bottle and the shutoff valve - the regulator should already be set to the correct pressure. Attach the tubing to the fitting at the back of the ion source (flush it first with Ar) and open the green valve, located on the underside of the ion source. The black tape indicates that the valve is open.

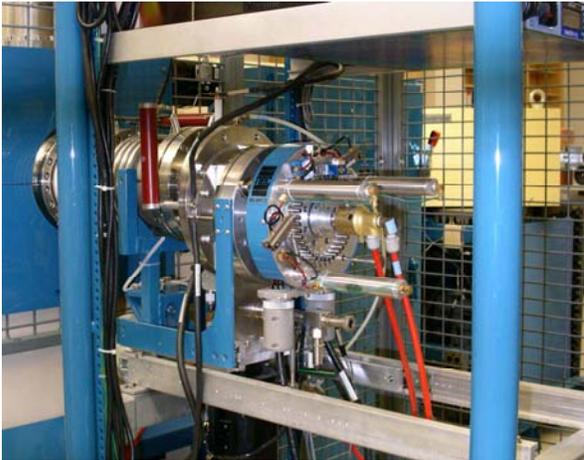


Fig. 8 SNICS Ion Source



Fig. 9 SNIC indexer controller panel and valve control box (below cryogenic pump)

13. Retract the sample changer by pulling on the two blue legs (you will have an immediately view of the wheel - fig. 11).

14. Remove the old wheel undoing the 8 bolts (one turn is enough) on central nut (fig. 11), and after undoing the nut from the hub. Grab wheel from hub. Tools are in plastic tray.

15. Put in new wheel. Do not touch the samples (wear gloves).

16. If you are not familiar with the procedure: Place the new wheel on the hub, aligning it with the pin. Screw the nut into the shaft, holding the wheel and forcing it center-clockwise. Screw down the 8 bolts in the nut

17. Push the sample changer forward (fig.11).

18. Remove the Ar tubing (close the gas bottle) and attach the roughing pump tubing. Switch the pump on and squeeze the sample changer flange against to the ion source body to seal the two faces - takes about 10 sec for pump to turn on).

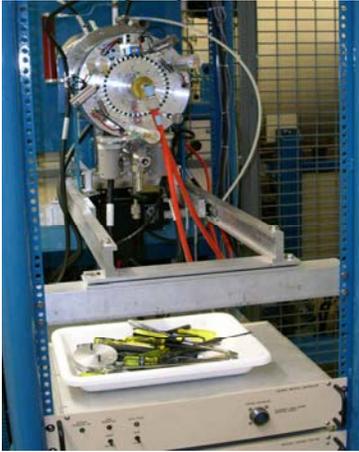


Fig. 10 SNICS Ion Source
(source controller box below).



Fig. 11 Ion source open (NEC wheel at left).

19. Wait for the vacuum at the roughing pump to reach <math><100</math> millitorr.
20. Close green valve (fig. 10) and turn off the roughing pump.
21. BE SURE THAT THE GREEN VALVE IS CLOSED (you should be able NOT see any black space above the yellow tape place on treade of the green valve) a and bypass the cryogenic pump gate valve interlock. Go to the electropneumatic valve controller (fig. 9) and switch from NLK ENABLE to BYPASS.
22. Open the gate valve from sample changer (switch on the ion source controller - fig.10).
23. Wait until the vacuum is below - 24. Insert wheel (switch on the ion source controller - fig. 10).
- 25. Check that the wheel is oriented correctly looking at the back of the ion source (zero on top - fig. 10). If not, go to SNIC indexer controller panel (fig.9) and switch from CHANGE to DISENGAGE to turn wheel manually and use the reverse and forward switch to correct orientation. Switch CHANGE to change one position. Repeat many times is necessary.
- 26. At the SNIC indexer controller panel, switch from LOCAL to REMOTE (fig.9).
- 27. Unplug the indexer controller cable from the controller box (fig. 10) and stow away cable.
- 28. Before turning the ion source on, look at cesium spots on previous graphite targets under microscope to make sure that the cesium beam was hitting the target in the right place. If not, adjust the 3 alignment knobs at the back of the ion source. If you do not know how to do it ask.
- 29. Close the cage, turn on S1 ITX and S1 HVS to warm up the machine.

VI. Preparing the RUNLIST

VI.1. Accessing the RUNLIST

```

csadmin@irvine1:~/datasets/vol2/Dec08_03 - Konsole
File Sessions Settings Help
alias's set l, ma
csadmin@irvine1>cd /datasets
csadmin@irvine1>ls
vol1 vol2 vol3 vol4 vol5 vol6 vol7
csadmin@irvine1>cd /datasets/vol2
csadmin@irvine1>ls
Dec02_03 Dec03_03 Dec04_03 lost+found
csadmin@irvine1>makebatch Dec08_03
csadmin@irvine1>cd Dec08_03
csadmin@irvine1>ls
runlist
csadmin@irvine1>

```

Fig.12 Konsole window screen.

1. Open a Konsole window screen. Use the monitor symbol at the bottom side of the desktop computer display.
2. Go to datasets directory and select the available volume, using the Linux commands as is shown at fig. 12.
3. Make new directory by typing “mkdir”.

4. To copy an old runlist, go to a high level directory first. Copy the contents of a previous runlist into new file:

cp[space]/datasets/vol#/prev_dir/runlist [space]/datasets/vol#/new_dir

5. Edit the file as required (type >emacs runlist - fig. 13) and save the buffer.

```

emacs@irvine1
Buffers Files Tools Edit Search Mule Help
#
# Irvine
#
# $Id: runlist.sample,v 1.0 2002/06/05 17:59:38 csadmin Exp $
#
# $Log: runlist.sample,v $
# Revision 1.0 2002/06/05 17:59:38 csadmin
# Initial revision
#
#
# batch control items -----
#
batch isotope 14C
batch source S1
batch park 0
batch mode nrm
batch autorange no
#
# run list items -----
# v-- run order v-- sample number
# v v-- group v v-- number of measurements to perform
# v v v-- mode time/counts(T/C)
# v v v-- # of cycles in measurement
# v v v-- sample type v v v-- # max number of even\
nts when mode=C
# v v v v v v-- warmup time \
in cycles v v v v v v
# 4 4 6 16 3 4 2 6 6 4
# Pos Grp SmType Sample Name Num Runs Md Tlimit Climit Warm
# =====
run 0 0 BAC Alpha_none 1 8 C 3000 35000 200
run 1 0 BAC Alpha_baked 1 8 C 3000 35000 200
run 2 0 COA UCIG_2149.2 1 8 C 3000 35000 200
run 3 0 OX1 UCIG_2132.1 0 8 C 3000 35000 100
run 4 0 OX2 UCIG_2140.1 1 8 C 3000 35000 100
--:-- runlist (Fundamental)--L1--Top-----
For information about the GNU Project and its goals, type C-h C-p.

```

Fig. 13 Runlist template.

6. Optional way to access the runlist:
 - a. Go to the pen symbol at the bottom of the left side of computer desktop and open the window. This window works, as a word document.
 - b. Select: file→ open→ datasets→ [respective volume]→ [directory file name]→ runlist.

- c. Edit runlist and save it.

VI.2. Editing the RUNLIST

If is your first time editing the runlist follow the next steps:

1. Do not modify the head of the runlist template. It has the information necessary to edit it.
2. Start to modify the lines respective to your sample list information (e.g., line that starts with command "run").
3. Highlight the wheel description and everything below it (e.g. the actual runlist) and select "print region" from the tools menu.
4. After, you finish modify your runlist, select: file → save. At this stage your runlist is save into the selected directory, but it is not loaded.
5. To load or set the new runlist, you have to come back to the previous window (fig. 12) by closing the emacs window.
6. Check if the runlist is correct, using the command [more runlist] at the prompt + enter bottom to check line by line (e.g., csadmin@irvine1>more runlist ↵), and set the runlist (e.g., csadmin@irvine1>set_runlist).
7. If, everything is correct you should see the message "runlist loaded successfully".
8. Go to the second main window of the Accelnet control System (fig. 4). Your runlist should be visible in the upper DMANmngr window (see fig. 14, as example), following some useful information: a) your batch directory pathname, where you can find the entire data related with this particular run; b) number of available and estimated blocks for this run (check if the number of blocks available is enough to save the data) and; c) action buttons that you will use after tuning the machine. Example:
 - stop** - to stop the run;
 - coll** - to start collection;
 - tune** - pause to tune the machine;
 - clear** – clear a individual run, if the stop bottom was selected previously;
 - endrun** - finish the entire run (e.g., the 40 samples).
9. Other commands can be found in the upper line of the DMANmngr window (see fig. 14, as example). They are **File**, **Runlist** and **Results**. The two last ones are the most useful ones. Example:

Runlist - allow the user to edit/change the information on a particular run line. For example, if the user decide to increase/decrease the number of runs to be performed in a particular sample. Go to Runlist → Edit → [edit window will be display] → select the sample to be modify by clicking at the respective line on the upper section of the DMANmngr window. The edit window will be filled up with the sample information. Select what information should be changed by click on it, the alphanumeric info will be display at the lower part of the edit window. Modify it, select enter button and apply. If you do not press enter before select apply, your request will be not performed.

Results - allow you to print the final results in hard copy (go to Results → print). This is only necessary if you use **Endrun** to stop the entire run before it has come to the end of the full runlist sequence. If the entire run is done automatically the hard copy will print out on its own.

Notice that the below area of the DMANmngr window is empty (fig.14). This area is reserved for measured results (to periodically check the results on line - section VI), when you finally start to collect.

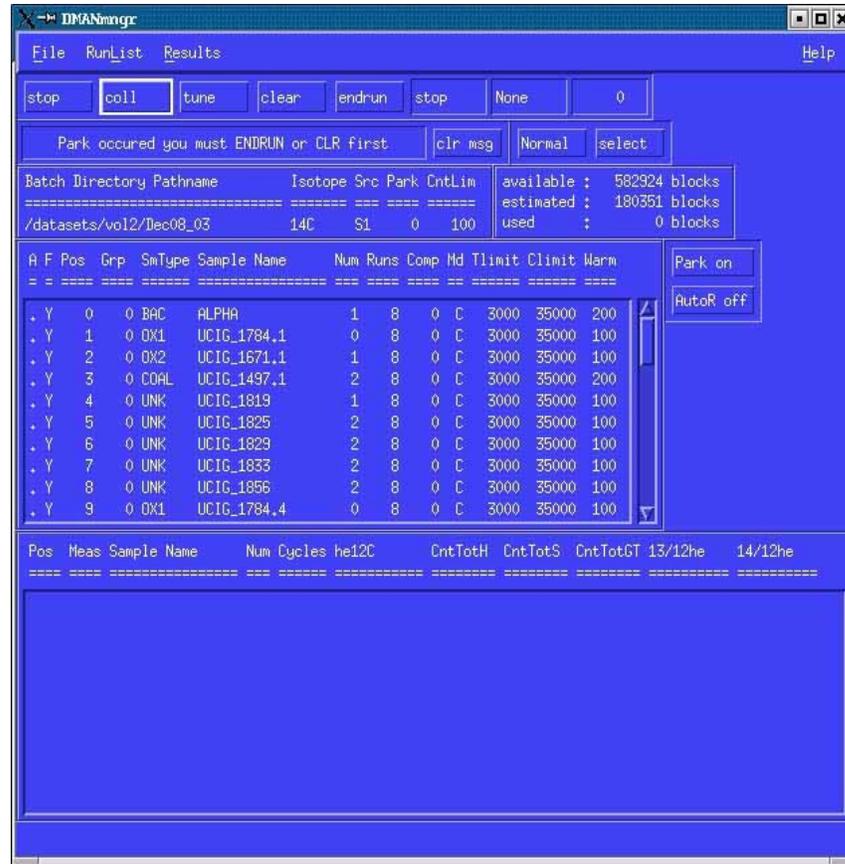


Fig 14. DMANmgr window (the blue window)

VII. To run the Accelerator Mass Spectrometer (settings and tuning)

VII.1. Start up the SNICS Ion source (warm up procedure):

The NEC SNICS ion source has gone through many modifications to provide more stable beam currents (Southon et al, 2003b). On January 2004, the ion source started to run with a new source body that provides better cooling and also better cesium delivery to the ionizer. The cesium reservoir and delivery tube have new configuration and the **S1 OVN2** parameter (fig. 7) does not have any function.

1. Make sure that the pressure at the LE beam line is $\leq 3 \times 10^{-6}$ (Check LE IGC1). If not, wait for it to decrease.
2. Use the mouse to turn on S1 ITX and S1 HVS (fig. 15). Left click activates the alphanumeric status and right click will change it - the ion source parameters will turn green from violet (table 1).
3. If the magnets are off, turn them on clicking at the inside boxes of the BM's (fig. 7) and changing the status from off to on.
4. Set BM currents (Amps) correctly to correspond to the ^{13}C BM values in Gauss (table 2).

Magnet	^{13}C setting (G)	^{14}C setting (G)
LE BM	~ 4115	~ 4270
HE BM	~ 7250	~ 7525

Table 2: Bending magnets settings.

5. Fine tune BM values by modifying the knobs from restore g2 (fig.16) and check if the values in Gauss from both the magnets were re-established (check table 2).

The fig. 16 shows the meters and knobs restore window that shows recorded groups of settings of the assignable meter/knobs (right side of the console - fig. 2). Each group restores a particular set of parameters of the machine that was saved, and can be monitored and tuned with the knobs. It is not necessary to memorize these groups.

6. Check if the magnet LE BM and HE BM are correctly set to ^{13}C values (table 2). If they are set for ^{14}C , you will need change the settings to correspond mass=13 (^{13}C).
7. Go to AMS tools (fig. 15) and press "set MfieldC = MfieldR". Make sure your click was truly effective by LFT clicking on the magnet LE BM icon until you see MfieldR and MfieldC values (unit - Gauss (G)). The values applied (control - C) and read back (read - R) should be identical.



Fig.15 meters and Knobs restore window



Fig. 16 AMS tools window.

8. Press "change $^{14}\text{C} \rightarrow ^{13}\text{C}$ " (then wait for the magnets to turn green from yellow - fig. 6). During BM changes, always keep the FC "in" to avoid accidents.
9. With the magnets set to ^{13}C , the user will be able to monitor the ^{12}C beam current growing on the LE MFC 1 off-axis Faraday cup inside the tank (restore g1 - fig.16), when ion source starts to "turn on". Note that "LE FC" actually monitors "LE MFC1".

During the warming up ion source procedure, only 3 parameters should be modifying by the user (fig.7). They are: ION \rightarrow Ionizer;

MCS \rightarrow multicathode (sample position from 0 to 39);

OVN1 \rightarrow Cesium reservoir voltage (controls the heater).

10. Open the BLV valve and remove the first FC (if still "in" - fig. 6).
11. Activate MCS parameter (fig. 7) to change the cathode to position "0 (zero) - home position status".
12. Set the ionizer (ION) to 23A and the oven heater (OVN1) to 120V.
13. When the temperature reaches $T = 160^\circ\text{C}$, decrease OVN1 to 110V.
14. When the temperature reaches $T = 165^\circ\text{C}$, decrease OVN1 to 100V.
15. When the temperature reaches $T = 175^\circ\text{C}$ or the ^{12}C beam current start to increase at LE MFC1 (restore g1 - fig. 16), decrease OVN1 immediately to 67V. This whole process should take no more than 20 to 30minutres. DO NOT FORGET TO TURN DOWN THE OVN1 OR BAD THINGS WILL HAPPEN - You will flood the source with cesium and it will spark uncontrollably until it is cleaned. During the run you may decrease OVN1 (check section VI).
16. If beam current does not increase inside the time frame mentioned above, the user should increase the ION from 23A to 23.2A and so on (by small increments of "0.2A") until the beam current "kicks up"). The ideal ^{12}C beam current to start tuning the machine for the run should be between 100-120 μA ($1.0\text{-}1.2 \times 10^{-4}$ at LE MFC1).

VII. 2. Tuning the AMS system with ^{13}C beam current

The system is tuned initially using ^{12}C and ^{13}C beams. The user stabilizes the ion source while monitoring the ^{12}C beam current in an off-axis Faraday cup (at LE MFC 1 - section V.1) and sets the major elements of the machine (magnets - BM's, terminal voltage, gas stripper and ESA) and ^{14}C corrective steerers, injecting the ^{13}C beam current through the accelerator. However, the intensity of the ^{13}C beam current is too high to be injected into the detector that is placed at zero degree at the end of beam line (fig. 17). An accidental injection of an intense beam current (^{12}C or ^{13}C) will "fry" the solid state detector (fig. 25). To avoid that, the last FC in the beam line is already interlocked (red box - default status) to not allow the user to open the Faraday cup accidentally during the ^{13}C beam tuning. **NEVER BYPASS THIS INTERLOCK DURING MACHINE SETUP.**

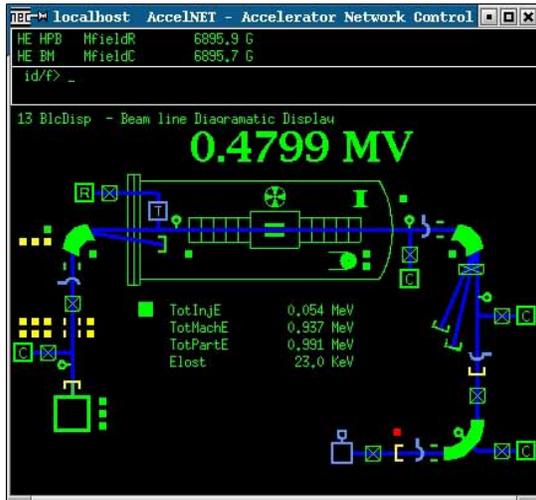


Fig. 17 Beam Line Diagrammatic Display (^{13}C settings)

To start tuning the AMS system with the ^{13}C beam current the beam line diagrammatic display window should look like figure 17, e.g., all the corrective jumping steerers and the bouncer at the LE side should be in maintenance (MAINT) mode (see steps 3 and 4 on section IV.1.).

Once the ^{12}C beam currents from the ion source is around $100\text{-}120\mu\text{A}$ ($1.0\text{-}1.2 \times 10^{-4}$ at LE FC), the user can start to tune the AMS system with the ^{13}C beam current.

1. Maximize the ^{12}C beam current at LE MFC 1, using the ion source parameters S1 CSF and S1 FOC (restore g1 - fig.16)..
2. The user can also monitor the shape of the total beam current that is being generated at the ion source, when tuning the FOC (Einzel lens). Select LE BPM from the BPM setup window (fig. 18).

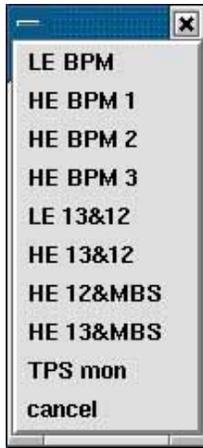


Fig. 18 The BPM setup

The Beam Profile Monitor (BPM) setup allows the user to monitor the shape of the beam current. This AMS system has 4 BPM's that together with the Faraday Cups complete the beam diagnostics set of the machine. Looking at the BPM's provided, the operator can maximize the beam current at the respective FC's, adjusting the settings of the machine.

LE BPM (fig. 19) → helps to evaluate if the ion source need more cesium to extract more ions + Cs beam current alignment (it is hitting the center of the sample);

HE BPM 1 (fig. 20) → helps to set the injection magnet (LE BM);

HE BPM 2 (fig. 21) → helps to set the analyzing magnet (HE BM);

HE BPM 3 (fig. 22) → helps to set the ESA;

HE 13 & 12 (fig. 23) → helps to maximize the $^{12,13}\text{C}$ beam currents at the FC's off-axis Faraday cup into the FC chamber (fig.17).

Parameters assigned at RESTORE g1

Meters: LE FC (LE MFC1), HE FC1 and HE FC2

Knobs:

3. Click LE BPM (fig. 18) to get peaks on oscilloscope (fig. 19).
4. S1 CSF → allows maximize the ^{12}C beam current at LE MFC1.
5. S1 FOC → allows maximize the ^{13}C beam current at HE FC1. Try maximize it, while maintaining "nice" looking peaks (not too skinny, symmetrical).
6. HE:LE FC should be about 0.47%.

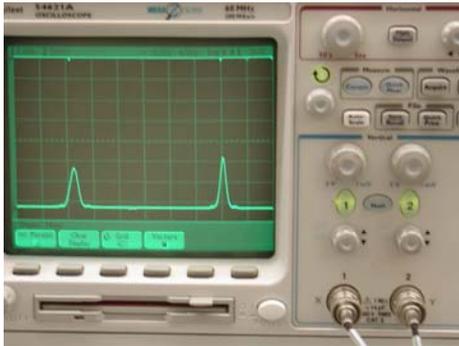


Fig. 19 LE BPM - (Y,X)

7. LE ESY (Vcreg2) → corrects the beam position (Y direction), using the ^{13}C beam current. Should not change too much from previous settings.
8. LE ESX (Vcreg2) → allows to correct "roughly" the ^{14}C sterrers (X direction), using the ^{13}C beam current. Should not change too much from previous settings.
9. After tuning, select cancel at the BPM set up (fig.18 - this stops the BPM).

Parameters assigned at RESTORE g2

Meters: HE FC1 and HEFC2

Knobs:

10. Click HE BPM1 (fig. 18) to get peaks on oscilloscope (fig. 20).
11. Adjust LE BM → watch RHS peak and get it 1mm off to the left of the fiducial mark ("blip") in the upper trace. Click "Cancel" to stop the BPM, then fine tune to maximize HE FC1 on digital readout.
12. Click HE BPM2 (fig.18) to get peaks on oscilloscope (fig. 21).

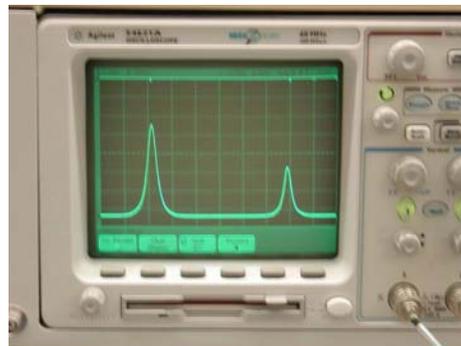


Fig. 20 HE BPM1- (Y,X)

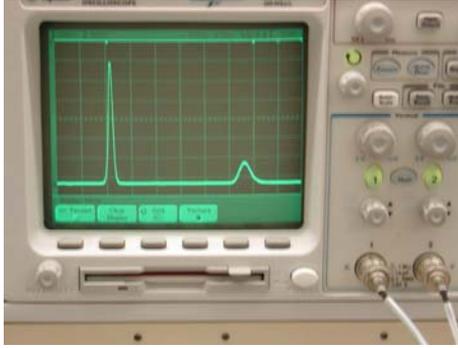


Fig. 21 HE BPM 2- (Y,X)

13. Adjust HE BM → watch RHS peak and get it 2mm to the left of the fiducial mark in the upper trace. Click Cancel to stop the BPM, then fine tune to maximize HE FC1 on digital readout.
14. Check HE:LE FC should be about 0.47% (or, LE/HE ~ 200).
15. Retract the HE FC1 to allow ^{13}C beam current pass thought ESA.
16. Adjust HE ESA → maximize ^{13}C beam current at HE FC2 (you should be able to get 99.5 to 100% of what you observed on HE FC1)
17. Insert HE FC1 to interrupt and read ^{13}C beam current.
18. Adjust (if necessary) the steerer HE MSY → to maximize the beam (should not change too much).

VII. 3. Tuning the AMS system with ^{14}C beam current

After the user has set the major elements of the machine using the ^{13}C beam current thought the accelerator, he/she can move both magnets to the ^{14}C beam current settings to peak up the ^{14}C count rate into the silicon solid state detector (fig. 25 and 26) under computer control. For the final tuning it is also necessary to vary systematically critical power supplies (bouncing voltage and jumping steerers) to peak up the $^{12,13}\text{C}$ beam currents at the FC's.

High precision AMS measurements are carried out by using fast sequential injection of the stable isotopes (^{12}C and ^{13}C) and ^{14}C . The sequential injection is achieved by modulating the ion energy at the injector magnet (LE BM). This fast switching between the 3 isotopes can be done by the periodic application of a voltage (bouncing voltage) to the vacuum box of the LE BM. For example, a small positive voltage is applied to the box to speed up the ions before they enter the LE BM and gives a ^{13}C or ^{12}C beam the same magnetic rigidity as the ^{14}C beam at zero bias voltage. The bouncing voltage also provides retardation as the ions leave the magnet so that they enter the accelerator with normal energy. After the accelerator, the ^{12}C and ^{13}C stables isotopes emerge from the analyzer magnet (HE BM) in an off-axis direction (HE MFC1 and HE MFC2 - fig. 22), where no bouncing voltage are being applied to this vacuum box.

Change the ^{13}C to ^{14}C settings

At this stage, it is necessary to change the magnet settings to allow ^{14}C particles pass through the machine. The proper ^{14}C settings for both magnets (LE and HE BM) will be achieved by computer calculation, based on the ^{13}C magnets settings obtained by the user (section V.2 - steps 10 and 13).

1. Insert LE FC. During BM's changes, always keep the first FC "in" to avoid accidents.
2. Go to AMS tools (fig. 15) and press "set MfieldC = MfieldR". Make sure your click was truly effective by LFT clicking on the magnet LE BM icon until you see MfieldR and MfieldC values (unit - Gauss (G)). The values applied (control - C) and read back (read - R) should be identical.
3. Press "change $^{13}\text{C} \rightarrow ^{14}\text{C}$ ", then wait for the magnets to turn green from yellow (fig. 6). This will take about a minute
4. Retract LE FC .
5. Pass jumping steerers from maintenance (maint) to normal (norm). Left click on right square boxes before BLV (turn yellow to green).

6. Pass injection magnet MBS (at the LE side) from maintenance (maint) to normal (norm). Left click on the left square box near the LE BM symbol (turns yellow to green).
7. Open all FC's and allow the ^{14}C beam current reach the silicon solid state detector.

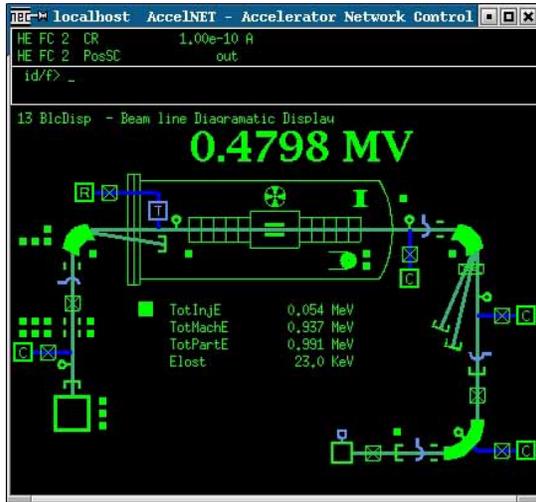


Fig. 22 Beam Line Diagrammatic Display (^{14}C settings)

To start final tuning to the AMS system with the ^{14}C beam current, the beam line diagrammatic display window should look like figure 22, e.g., the bouncer and all the corrective jumping steerers at LE side should be in normal (NORM).

8. Go to the second main window of the Accelnet control System (fig. 4) to have access to the Dosimetry operation (fig.24), HISTmngr. (fig. 25) and DMANmngr (fig. 27) windows.
9. Go to the Dosimetry operation window (fig. 24).
10. Move to a standard (OX-I or OX-II). Change on the S1 MCS (fig. 24) the cathode position to the nearest modern standard.
11. Set the cycle mode (CycModeC) to continuous run ("cont_run"). Left click to activate the parameter to be changed. Right and middle click to change the mode to "cont_run".
12. Start to collect by changing the "BusySR mode" from stop/pause to run/coll. Left click to activate the parameter to be changed. Right click once to change the mode.

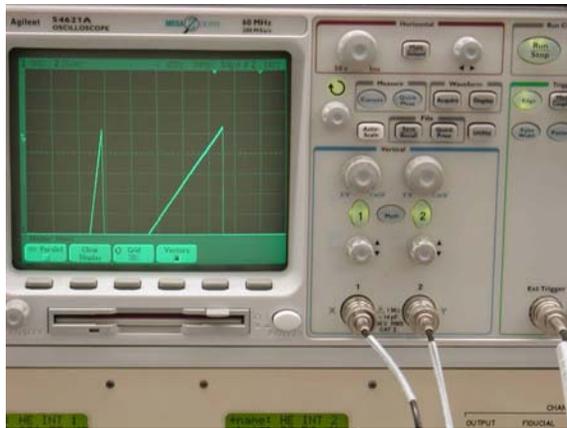


Fig. 23 HE BPM ^{12}C & ^{13}C

13. To clear the counts and the $^{13}\text{C}/^{12}\text{C}$, $^{14}\text{C}/^{12}\text{C}$ and $^{14}\text{C}/^{13}\text{C}$ ratios displayed, leave the "BusySR mode" on pause and request from the "ClearSC" to clear the display. Left click to activate the parameter to be changed (nop). Right click once to clear.
14. Click HE 13&12 at the BPM window (fig. 18) to get the integrated signals of the ^{12}C and ^{13}C beam currents on the off-axis Faraday cups (fig. 23).
15. Adjust the oscilloscope traces by manipulating the knobs channel(1) for ^{12}C and channel(2) for ^{13}C curve, adjust to the highest sensitivity that will keep the top of each peak on the screen.

Parameters assigned at RESTORE g4

Meters: HE MFC 1 (^{12}C on FC off-axis direction)

Knobs:

16. MBS (Vcreg0) → positive voltage (~ 9.200kV) applied to the vacuum box of the LE BM to give the ^{12}C beam the same magnetic rigidity as the ^{14}C beam.
17. LE ESY (Vcreg0) → corrects the ^{12}C beam position (Y direction), when the bouncing voltage is activated.
18. LE ESX (Vcreg0) → corrects the ^{12}C beam position (X direction), when the bouncing voltage is activated.

Maximize the ^{12}C signal (left hand peak) by tuning the three knobs. Save each of the values by clicking the buttons "save" nearby respective knobs.

Parameters assigned at RESTORE g5

Meters: HE MFC 2 (^{13}C on FC off-axis direction)

Knobs:

19. MBS (Vcreg1) → positive voltage (~ 4.200kV) applied to the vacuum box of the LE BM to give the ^{13}C beam the same magnetic rigidity as the ^{14}C beam.
20. LE ESY (Vcreg1) → corrects the ^{13}C beam position (Y direction), when the bouncing voltage is activated.
21. LE ESX (Vcreg1) → corrects the ^{13}C beam position (X direction), when the bouncing voltage is activated.

Maximize the ^{13}C signal (right hand peak) by tuning the three knobs. Save each of the values by clicking the buttons "save" nearby respective knobs.

The steerer values should be very close to those for ^{12}C (you can check the values by RESTORE g4 and g5 or by left clicking on the steerer boxes - fig. 22).

```

localhost AccelNET - Accelerator Network Control System
SEQ      BusySR      run/coll
SEQ      StartSC      nop
id/f> _

14 DOSE  - Dosimetry operation

LE MFC 1 1e12C    -5.47e-07 A    -5.4643e-07 A    0.9531 13/12rat
LE MFC 2 1e13C    -5.08e-09 A    -5.2082e-09 A    100.00 %
                                                100.00 %

HE MFC 1 1e12C     3.22e-05 A     3.1441e-05 A
HE MFC 2 1e13C     3.48e-07 A     3.4738e-07 A    1.1049 13/12rat

DOSE      CntRate      20,500 Cnt/Cyc
          CntTotH      10243 Cnts
          CntTotS      10225 Cnts
          CntTotGT      10205 Cnts
                                                1.182e-12 14/12rat
                                                1.070e-10 14/13rat

SEQ      BusySR      run/coll
          ClearSC      nop
          EndRunC      nop
          CollMode      collect
          CycModeC      pass_stop
          CntDwnR      440          3000

S1 MCS          9          InPos      rest
  
```

Fig. 24 Dosimetry operation window (inverted background color).

Parameters assigned at RESTORE g6

Meters: Dose (Cnt Rate)

Knobs:

22. LE ESY (Vreg2) → corrects the ^{14}C beam position (Y direction).
 23. LE ESX (Vreg2) → corrects the ^{14}C beam position (X direction).

These can be tuned, but it usually easier to just set them to the averages of LE ESX and LE ESY obtained for ^{12}C and ^{13}C .

For example:

	MBS (kV)	ESY (V)	ESX (V)	
^{12}C (Vreg0)	9.232	19	-35	→ Values obtained by tuning.
^{14}C (Vreg2)		24	-36	→ Values calculated (average).
^{13}C (Vreg1)	4.307	28	-38	→ Values obtained by tuning.

Table 3. Usual jumping steeres values.

Determine the electrostatic spherical analyzer (ESA) plateau:

To define the two borders of the ESA plateau, the user will have to change continuously the ESA settings and observe the final $^{14}\text{C}/^{12}\text{C}$ ratios obtained, using a standard (OX-I or OX-II sample).

24. Select an ESA setting and note it down.
 25. Go to Dosimetry operation window (fig.24) and select “run/coll” to start to collect (right click).
 26. After about 10,000 counts, stop collecting (central click) and record the $^{14}\text{C}/^{12}\text{C}$ ratios obtained.
 27. Change the ESA setting by 50V each time.
 28. To clear the ratios displayed in the Dosimetry operation window, select the “nop” next to “ClearSC”.
 Left click to activate the parameter to be changed (nop). Right click to clear.

Modern Standard	$^{13}\text{C}/^{12}\text{C}$	$^{14}\text{C}/^{12}\text{C}$
OX-I	1.100	$1.17 \cdot 10^{-12}$
OX-II	1.100	$1.51 \cdot 10^{-12}$
OX-II/OX-I ~1.29		

29. Repeat the steps 24 and 26 many times are necessary until the $^{14}\text{C}/^{12}\text{C}$ ratios drops from value expected (see table 4) by a few percent. Find the upper and lower edges of the plateau and set the ESA in the center.

Table 4. Radiocarbon rations of the standards

30. Final check the $^{13}\text{C}/^{12}\text{C}$ and $^{14}\text{C}/^{12}\text{C}$ ratios. They should be similar to the values display on table 4.
 31. Verify the $^{14}\text{C}/^{12}\text{C}$ ratios from standards in the wheel to make sure they give decent ratios.



Fig.25 silicon solid state detector.

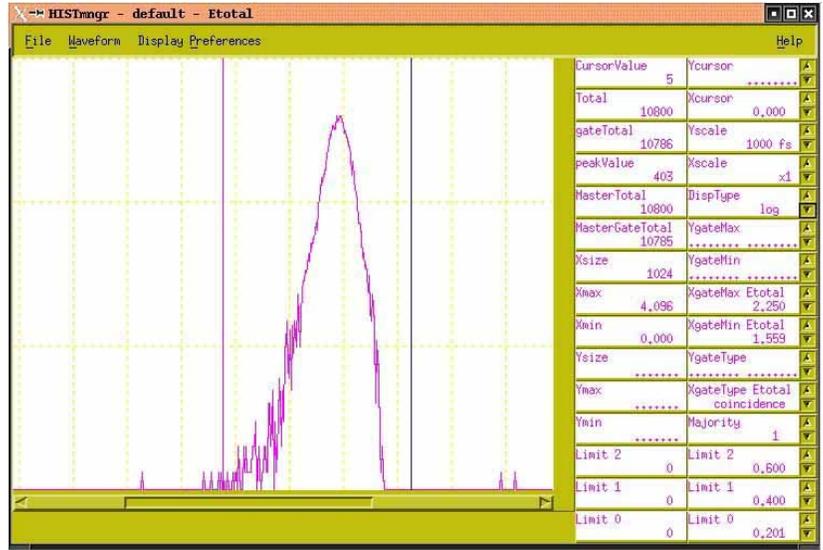


Fig.26. the HISTmng window(inverted background color).

32. Make sure that the gate window on the HISTmng window is set properly. This gate window was defined by measuring the modern standard and should not change, except if the silicon solid state detector (fig. 25) is damaged or is being degraded after a long period of use.
 - a. X-gate min → just above the peak.
 - b. X-gate max → just below the peak.
 - c. Use the up and down arrows to adjust if necessary.
33. If everything looks good, hit “COLL” on DMANmng window (the blue window - fig.14).
34. At this stage, you can bypass the last FC interlock (HE FC2). Go to the box above the Faraday cup. Left click to activate the parameter and right click once to change the status from nkl (interlocked) to bypass. The box will turn yellow from green. If you do not do this a small glitch may cause the cup to be inserted and data collection will cease.

VIII. Checking the results on line (to "baby-sit" the machine)

The user should periodically check the settings of the AMS system during the run (computer controlled run) to notice eventual malfunction or drifts from parameters previously set.

From the SNICS S1 window (Ion source settings - fig. 7):

1. Check CSF current flow → should be stable and preferably < 3 mA (see section VII.2).
2. Check EXT current flow → should be stable and < 4 mA (if too high, the source will start to spark and the power supply may be triggered).
3. Check OVN1 temperature → should be ~ 150-155°C (varies a few degrees - always verify previous running settings). OVN1 heater should be ~ 67V.

From the DMANmng window (fig. 27):

4. Most samples should give ^{12}C beam current (HE MFC 1) around 45 to 50 μA . If beam currents jump dramatically, the user should stop the run and verify the settings of CSF and FOC. Huge changes will definitely affect the final results. Restore g1 and fine tune CSF and FOC looking to the HE BPM ^{12}C & ^{13}C - Fig. 23.
5. Check spread on $^{13}\text{C}/^{12}\text{C}$ and $^{14}\text{C}/^{12}\text{C}$ ratios from primary and secondary standards. The spreads should not exceed 5‰ and 10‰ respectively.

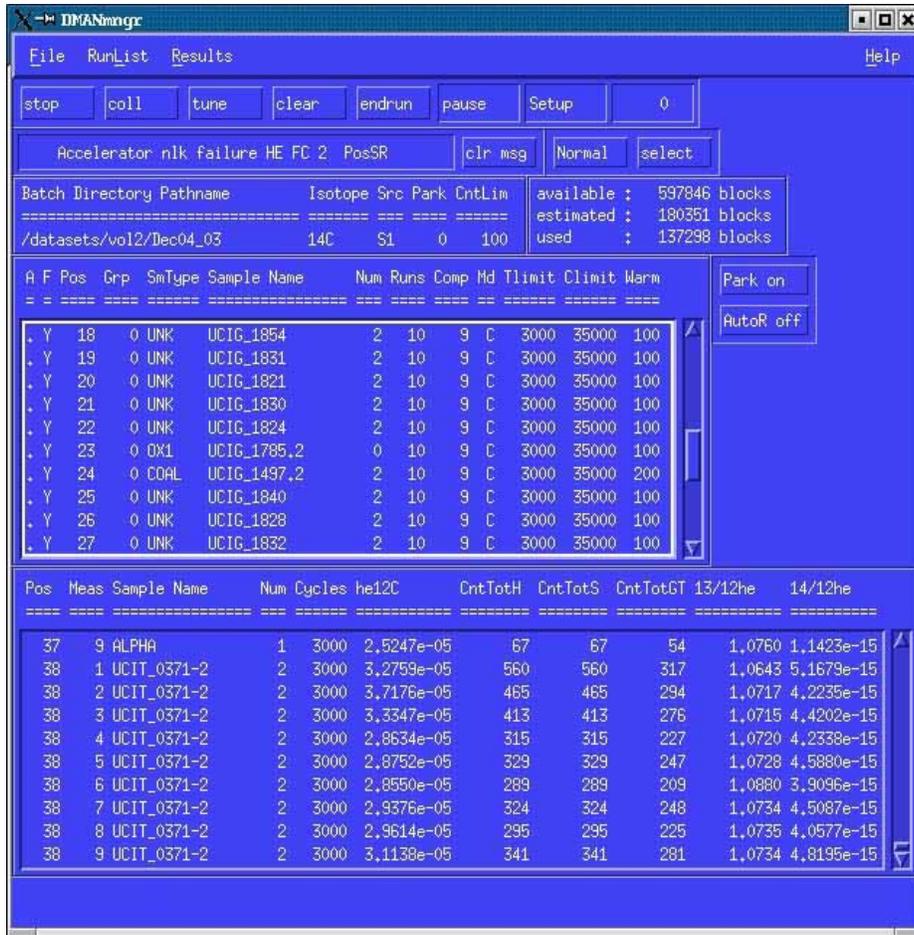


Fig.27 DMANmgr window with a runlist loaded and running.

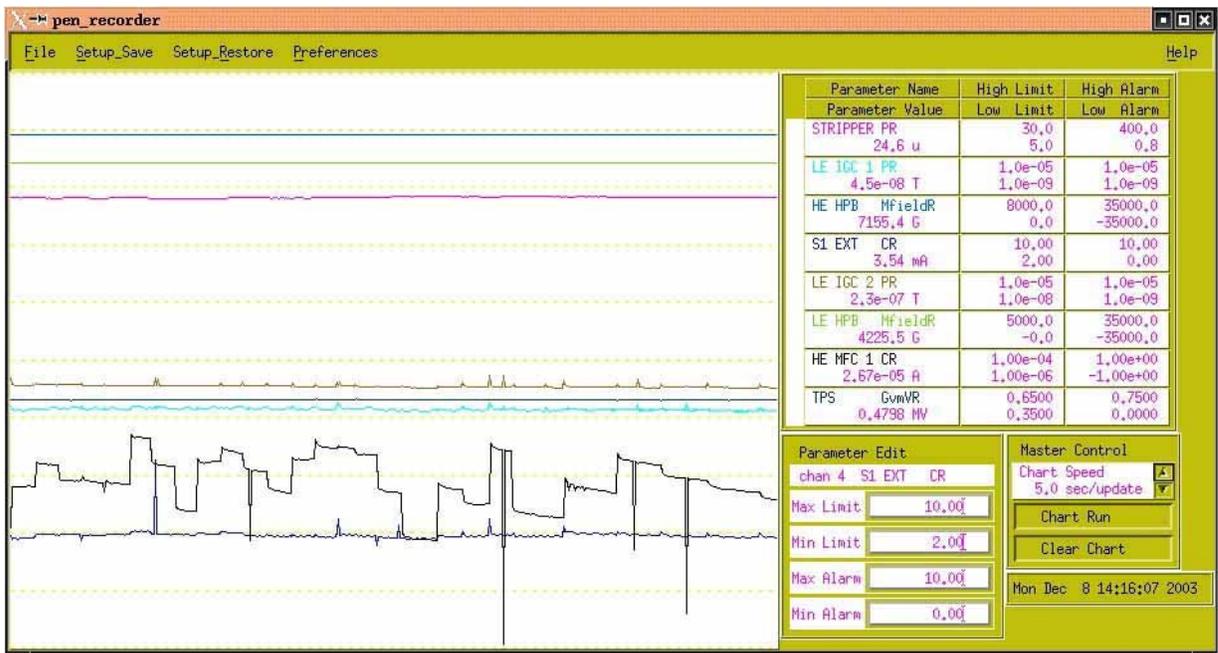


Fig.28 Pen-record window (inverted background color).

From the Pen-recorder window (fig. 28):

The pen-record window records parameters of the accelerator that should be monitored during the run. The operator may find some of the parameters already selected. However, they can be modified by convenience of the user.

To modify existing parameters:

The pen record can monitor 8 parameters each time. The available spaces are record from top to bottom by numbers 1 to 8. To modify the existing parameter, select what one you would like to replace, click on the alphanumeric value or icon to select the parameter to be monitor (left click on mouse) and write at the prompt of the window where you select the new parameter "pen" and respective number where you would like the parameter to start to be recorded. For example, the gas stripper is being recorded on the first window at the pen-record (fig. 28). To modify it for CSF value, the user has to select from the SNICS S1 window at the Accelnet Control System (fig. 6) the respective parameter and in the same window write into the "prompt id/f>pen 1". The CSF value will automatically replace the previous one.

Parameters that should be monitored any time:

6. Check EXT current flow increases during the run. If looking too high, reduce the ionizer current ION (by 0.2A increments and wait at least 10 min between adjustments). By reducing the ION, you may lose beam current. Check ¹²C beam current (HE MFC 1). It's a trade off!
7. Do not worry when EXT current flow jumps up ~1mA for machine background samples, such as Alphas and Ultras (they are synthetic graphite and behave differently from the other samples).
8. The gas stripper pressure should operate in a very specific range (23.5-25μ). If too high or low, you may need to change it.

A gas stripper consists of a small bore metal tube into the center of which gas is leaked at a slow rate. Ion stripping occurs when the beam passes through the gas and can be optimized by adjustment of the gas pressure. To minimize pressures in the accelerator tubes gas leaking out of the ends of the stripper is re-circulated by turbo pumps.

To change the gas stripper pressure:

- a. Go to Beam Line Diagrammatic Display window and left click on the gas stripper symbol (fig. 5) to check the current value.
- b. Left click again on the symbol until you see the value that indicates the number of turns applied to the gas stripper valve. The units are display as TRN (turns).
- c. Right click briefly to open the valve slightly and center click briefly to close it. Stop as soon as you see the display flash "open" and "close" briefly.
- d. The system has about three clicks of backlash if you are changing direction, e.g. if the last adjustment was down and you want to go up, the valve will not respond until the 4th click. Wait 20 seconds after each click to check if the system responds.

IX. Miscellaneous

IX. 1. Very important tips:

1. Make sure to save all settings for each individual group of parameters at the meters/knobs (click save button) once you decide on the optimal values. In this case, you will be able to restore them.
2. Make sure to turn off the beam profile monitor (BPM) when you finalize to check the peaks on the oscilloscope (by clicking "cancel" on the BPM setup window - fig. 18). The BPM will disturb the beam current during measurement.
3. To print the optimal settings for the day, go to AccelNET window → logging → log ALL small. Stick the copy on runlog-book for further reference.
4. When final tuning the machine using a standard sample (OX-I or OX-II) avoid staying on one target for a prolonged time period (>>15 min) to minimize burn-through.

IX. 2. Cesium focus (CSF) misbehaving (how to proceed):

1. IF CSF currents goes very high (> 3mA) on the SNICS S1 window (fig.7) there may be current flowing over dirty insulators that need to be clean up.
2. Note the initial voltage setting of CSF.
3. Change CSF voltage to 6V.
4. Wait 30 seconds (watch the CSF current on the SNICS S1 window readout screen). The CSF current will go very high (10-12mA), but should start to drop after some seconds.
5. Restore the original voltage setting. The CSF current should be lower.
6. Repeat as necessary until CSF current is below 3mA and stable.

IX. 3. To check the ^{12}C , ^{13}C beam currents and event/cycle at the "abc - NEC AMS Analysis Program":

The "abc - NEC AMS Analysis Program" is the data acquisition and data reduction (on line) designed to deal with the data analysis of the AMS system. abc is not used for data reduction at KCCAMS, but a monitoring feature of abc allows the user to see ^{12}C , ^{13}C beam currents and event/cycle from each independent run. To trace glitches, sparks and power supply malfunctions the user may find the "abc program" useful.

1. To begin running "abc" login in at Irvine 2 computer.
2. Open a window and type "wave" at the prompt (\$wave ↵).
3. Following type "abc" at the prompt (>abc ↵)
4. Select "1"
5. Select enter for the ID identification and select ok.
6. Select "read files"
7. Select the volume and file of choice (ex: Vol5, directory name: Jan21_04)
8. Select "read all runs"
9. Select "per cycle"
10. Select "Plot 3"
11. Select "events/cycle," or events/HEO," depending on what you're looking for.
12. A plot with the respective measured results will show up on the screen with the respective group of run samples (don't exit; keep this pop-up screen open).
13. Click on any cathode samples at the black screen (a new plot will shows up on the screen)
14. The two first plots show the ^{12}C and ^{13}C beam currents at the off-axis FC's, the third plot shows the ^{14}C count rate or $^{14}\text{C}/^{12}\text{C}$, and the fourth shows $^{13}\text{C}/^{12}\text{C}$.

15. Select next or previous to see run by run from the respective cathode sample.

X. References

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