The EMU User Guide

ISIS Neutron & Muon Source, Rutherford Appleton Laboratory

Science & Technology Facilities Council

Index

1 Introduction

The EMU spectrometer has 96 detectors, each comprising of a scintillator, light guide, and photomultiplier tube (PMT). These are arranged in two banks facing each other on opposite sides of the sample position. Each of these detector banks is further divided into three rings of 16 detectors. Coaxial cables take the PMT signals to the data acquisition equipment in the rear of the instrument cabin. There are three sets of magnets that can be used with EMU: the main magnet producing up to 4500 G (5000 G if required), transverse field coils producing up to 150 G and fixed zero-field compensation coils. The instrument is constructed around a ‘cruciform’ which is usually pumped and provides the insulating vacuum for cryostats. Sample environment equipment can be introduced through the ports. A tank can be attached to the downstream end of the magnet to ensure that fly-past muons stop well away from the detectors.

The instrument cabin has computers for controlling the spectrometer through the SECI program, monitoring the progress of the experiment, and carrying out data analysis.

Samples should be mounted in the prep lab across the loading bay from the instruments and cabins towards the synchrotron. Any sample preparation should be done on a tray labelled with one of the forms kept in the lab door, and all equipment used should be tidied away when finished.

2 Getting Started

2.1 Starting

Before starting data collection users should check the following points:

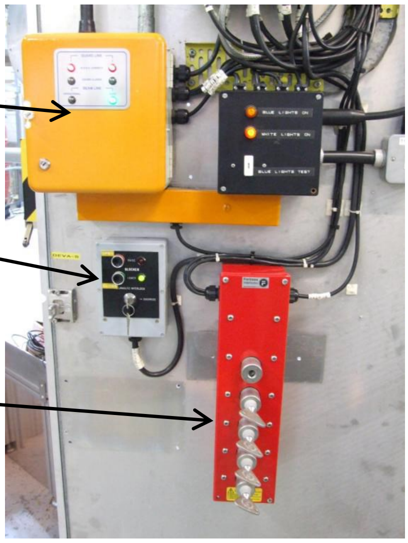
- Sample is loaded in a suitable container which is correctly masked.
- The fly-past tube is mounted if this type of experiment is to be carried out.
- The sample environment is suitable for the experiment.
- The automatic compensation system for the Earth's magnetic field is operating correctly.
- Slit setting and beam steering are correct.
- Suitable magnetic fields are available for:
  - (a) calibrations,
  - (b) measurements.
- The instrument control program, SECI, is properly set up.

2.2 Operating the EMU area interlocks

Status Lights

Shutter Control Buttons

Interlock Key Box (all the keys are the same)



Typical lock on area and sample position doors

Search Button

Beam Off Button

2.2.1 Closing the area

The blocker which prevents muons entering the EMU area can only be raised once the area interlocks are complete. For this to happen:

1. Close the gate allowing access above the spectrometer from the EMU platform and insert its key into the key box to the right of the area door. Turn the key clockwise.
2. Check that no-one is inside the EMU area and press the search button that is located on the right hand wall of the area. A loud buzzer should be heard.
3. Close the area door and remove the key from the lock. Insert its key in the key box to the right of the door, turning it clockwise.
4. The key box should now be full – check that all the keys are turned fully clockwise.
5. The blocker can now be raised: press the 'Open Blocker' button and hold until the green 'closed' light goes out. 'The Beam On' light and blue lighting in the area should turn on.
6. Anyone still in the area when the blue lights come on should press one of the 'Beam Off' buttons.

2.2.2 Entering the area

To enter the EMU area:

1. Unless necessary for your experiment, ensure the magnetic field is set to zero. Confirm that the 'Magnet On' light is extinguished.
2. Press the green 'Close Blocker' button. The 'Beam On' light should turn off and the white lights in the area turn on.
3. Remove keys from the red box starting at the top to open the ground floor or upper doors as required.

2.3 Common SECI commands:

Starting a Run

Type `begin`

Ending a Run and saving the data

Type `end`

Ending a run without saving

Type `abort`

Pausing a run

Type `pause`

Then to continue the run

Type `resume`

Setting a temperature (of *value* K)

Type `settemp` *`value`*

Setting a field (of *value* G)

Type `setmag` *`value`*

Setting the slit position

Type `slits` *`value`*

Selecting T20 power supply and setting 20 Gauss

Type `TF20`

Selecting Danfysik power supply

Type `lf0`

Selecting auto-zerofield

Type `f0`

Waiting for *value* seconds

Type `sleep` *`value`*

Setting the label

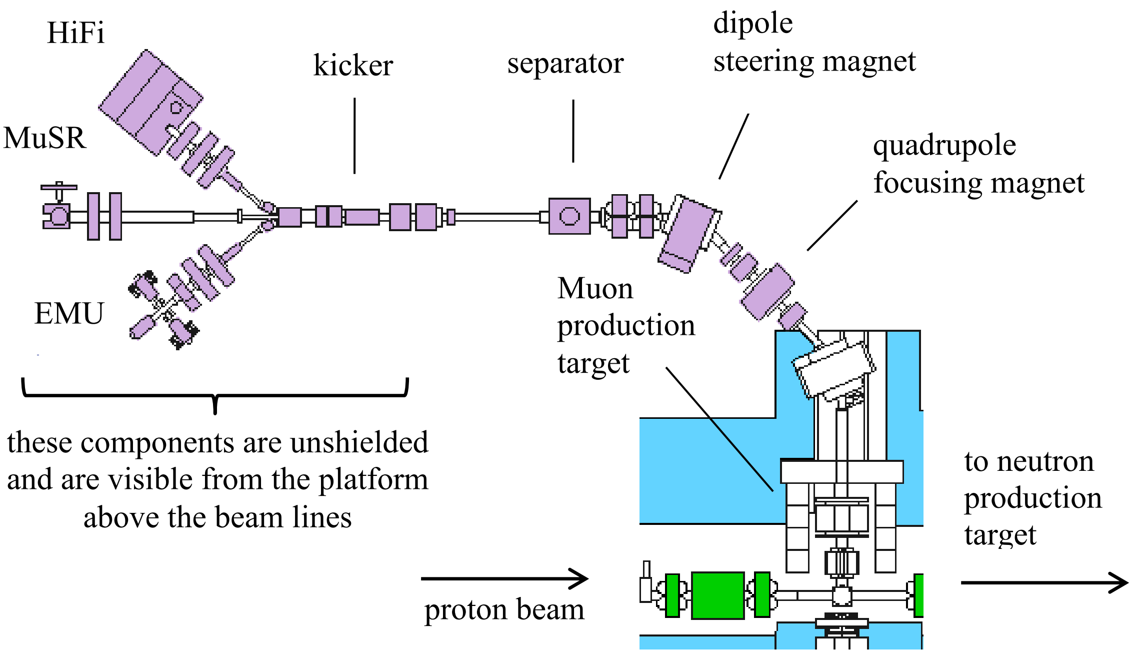
Type `setlabel` /qualifier

- `/s` for sample
- `/c` for comment
- `/u` for user
- `/rb` for rb number
- `/t` for temperature
- `/f` for field
- `/g` for geometry
- `/o` for orientation

You will be prompted for information.

3 The Facility and EMU Spectrometer

The following figure shows the general arrangement of the European muon facility at ISIS.



General layout of the European Muon Facility at ISIS

EMU receives part of the first of the two pulses of surface muons that come from the muon target every time the ISIS synchrotron sends protons towards the neutron target. Before it reaches the spectrometer it is focused and steered to control where the muons hit the sample in the cryostat. This is done using a combination of dipole and quadrupole magnets (shown above). The focussing and steering of the muon beam will have been checked during the calibration period at the start of each ISIS cycle. If a change to the focussing or steering is required for your experiment you should speak to your local contact. The two pulses of muons that travel from the muon target are separated using an electrostatic kicker before the EMU and HiFi beamlines branch off from the MuSR beamline. This uses a large DC voltage to split the first of the two bunches of muons so they can be steered into EMU and HiFi; the second pulse then continues on to MuSR.

4 Sample Environment

The following sample environment equipment is available on EMU:

Equipment	Temperature Range
Closed cycle refrigerator	8 K – 350 K
Oxford Instruments Sorption cryostat	350 mK – 50 K
Oxford Instruments Variox cryostat	1.5 K – 400 K
Oxford Instruments Flow cryostat	4 K – 400 K
Dilution Refrigerator	30 mK – 5 K (300 K)
Hotplate Furnace	300 K – 1000 K
Reflector Furnace	300 K – 1500 K

4.1 Closed-cycle refrigerator

SECI Configurations: CCR.conf, CCR_highT.conf, CCR_RhFe.conf

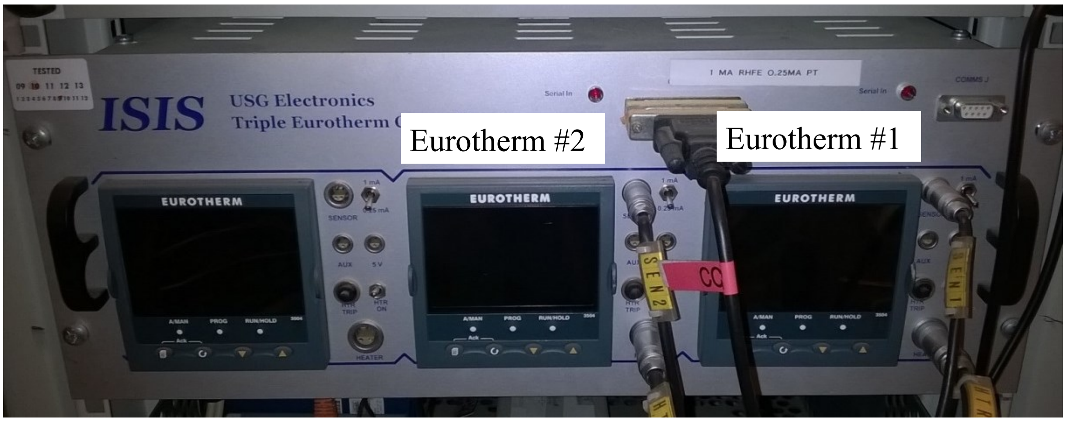
The CCR operates from 8 K – 800 K, however two thermometer ranges are required to cover this region accurately.

4.1.1 Thermometer selection

Ask your local contact to switch between the RhFe and Pt thermometers as required.

8 K – 350 K

This only uses the RhFe (30 point calibrated thermometer). The heater should be plugged into Eurotherm #2 (see below). The RhFe is used as both the control and the sample thermometer. This means that it is important to **turn the heater off when changing sample**, otherwise the head can be cooked! Always ensure that the thermometer is properly clamped. Configuration required: CCR_RhFe.conf.



20 K – 350 K

This uses the Pt as the control thermometer and the RhFe as the sample. The heater should be plugged into Eurotherm #1. This is safe as the control thermometer is always attached to the CCR. It will go to base temperature, however because the Pt is the control it will only allow base temperature control and then 20 K upwards (the Pt thermometer becomes sensitive at this temperature). Configuration required: CCR.conf.

30 K – 800 K

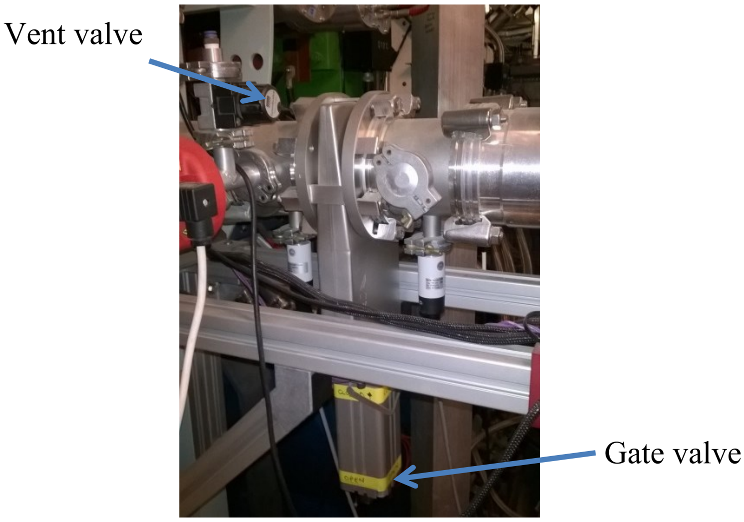
Two Pt thermometers are required. The effective range is from 30 K – 800 K (note the RhFe has a better calibration in its effective range). Heater should be plugged into Eurotherm #1. Configuration required CCR_highT.conf.

4.1.2 Loading a sample and cooling the CCR:

- Make sure all parts of the CCR are perfectly dry, using the hairdryers if necessary.
- Screw the sample blade onto the end of the CCR, using the small brass screws provided.
- Ensure the correct thermocouple has been selected (Pt for high temperatures and FeRh for temperatures less than 30 K) and that this is secured to the back of the sample blade with a small screw.

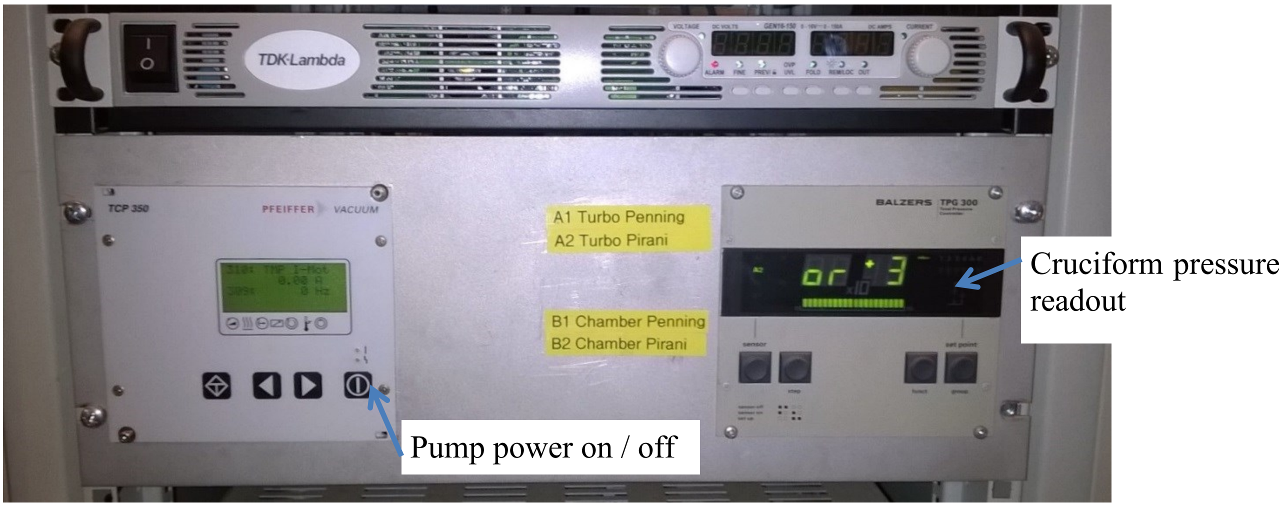
DO NOT BEND THE THERMOMETER LEADS.

- Replace tail sections. Take particular care when replacing the end section, ensure firstly that the windows are aligned correctly and secondly no part touches the sample.
- Slide the CCR unit into the spectrometer ensuring that it mates correctly with the flange mounted on the instrument. There is no need to secure the unit with bolts. Ensure that all the other ports are closed off.
- Close the cruciform vent valve.
- Fully open the large gate valve by winding the handle.



- Start the vacuum pump (using the right-hand button on the TCP350 panel). Both the Edwards rotary pump and the turbo pump will start to spin up. The rotation speed of the turbo is displayed on the panel. It should reach a speed of 1000 Hz (over ~ 20 mins).

- The cruciform pressure is displayed by the digital readout adjacent to the pumping unit controls.
- Below 10^{-3} torr the compressor may be switched on by turning the rotary switch on the compressor box. There will be a 10 second delay before the unit starts.



Users should check that the correct heater has been switched on and is not open circuit, by attempting to maintain a temperature slightly above room temperature before cooling the CCR.

4.1.3 Changing the sample:

- Set the temperature to 300 K.
- Turn the compressor off (to speed warming of the sample).

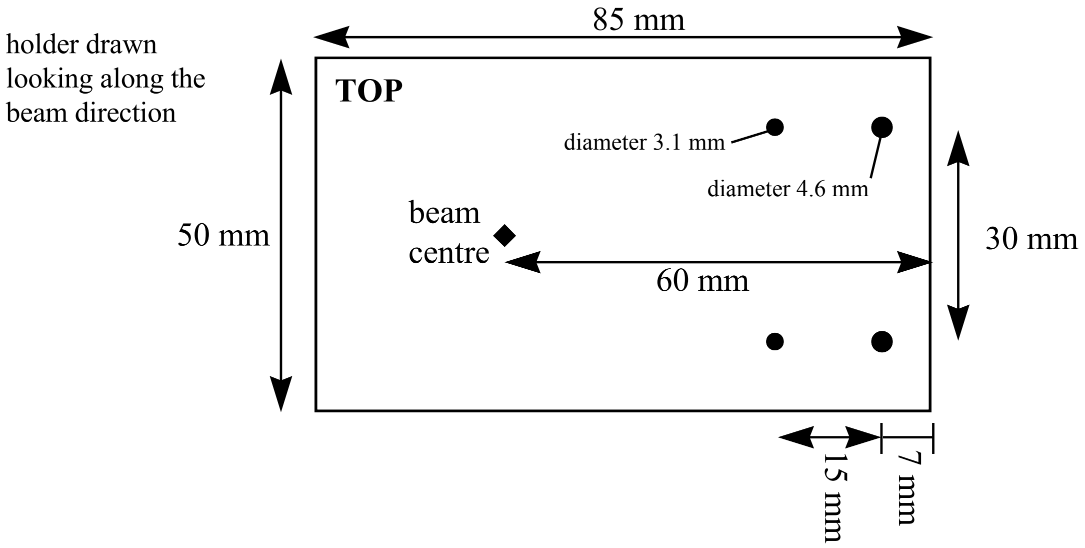
Then:

- Close the large isolation valve on the side of the cruciform.
- Switch off the pump using the right-hand button.

After the sample temperature has reached about 280 K and the pump has slowed down to below Hz:

- Open the upper vent valve to vent the cruciform.
- Slide back CCR unit.
- Switch off the heater.
- Remove tail sections and change sample.

4.1.4 Sample holder



4.2 Sorption cryostat

SECI Configuration: he3.conf

The sorption refrigerator operates between 350 mK and 50 K. The ISIS Sample Environment group and the local contact will assist with the sample mounting and cooling process.

4.2.1 Sample mounting

1. Mount sample onto the sample blade, using the usual precautions for low temperatures and cold finger cryostat.
2. Clean and re-grease both sides of the cone seal, then pump and rotate the sample can by 180 °.
3. Put on the sorption cryostat tails and pump OVC.

4.2.2 Computer control

1. Change the configuration to the He3 Sorption Cryostat.
2. Ensure the VI's in both tabs (Muon Temp Panel and He3) are running.

4.2.3 Condensing the He3, cooling to base

1. On the Upper ITC5, Set the Sorp temperature to 40 K. Please ensure that heater 1 is selected.
2. On the Lower ITC5, Cool the 1 K pot to 1.6 K, as a rule the 1 K pot pump pressure should be ~6 mbar and the needle value ~10 - 12 %.
3. Leave for 30 minutes with the 1 K Pot temperature less than 1.7 K and the Sorp at 40 K.
4. Cool the sorp to 4 K, open the needle value to ~25 %, but remember to close the needle value as soon as it is cold. Failure to do so will result in the needle valve freezing.

5. Ensure either the high temp/low temp switch is on low temp or the heater 1 or 2 on the lower ITC5 is selected. Failure to do so will reduce the He3 hold time from 30+ hrs to 2 hrs.

4.2.4 Heating and cooling above 1.6 K

1. Send a set point and ensure that the high temp/low temp switch is on high temp.
2. On cooling back down from high temp. Send a set point and heat the sorp to 19 K. The cooling power is low and this can take a long time.

4.2.5 Sample holder

Sample holders designed for the MuSR dilution fridge or the EMU Variox cryostat can be used in the sorption cryostat; however, users should avoid holders made of Al and other materials which undergo a superconducting transition at low temperatures.

Please remember to bring some thin (~10 µm thickness) silver foil to use as a heat shield.

4.3 Oxford Instruments Variox Cryostat

SECI Configurations: Beast_itc502.conf, Beast_itc503.conf

OpenGENIE Commands: `blue_lt` (operation below 4.5 K)

`blue_ht` (operation above 4.5 K).

The SECI command chosen will depend upon the sample stick currently in use. For stick 2 use Beast_itc502.conf while for stick 3 use Beast_itc503.conf. If the stick is changed during the experiment it is important to change the configuration for the new stick.

At this point both the heat exchange and sample temperatures should be correctly displayed in the temperature window within SECI. If this isn't the case try selecting the temperature controlling device at approximately five minute intervals.

4.3.1 Setting up

The cryostat will be craned into place by your local contact and the necessary electrical connections made. The ISIS sample environment group will endeavour to maintain suitable cryogen levels during your experiments but it is important to check that it contains sufficient cryogens before leaving it unattended for any period. Both helium and nitrogen levels should be monitored.

4.3.2 Loading a sample

1. Ensure the sample stick is completely dry before inserting it into the cryostat.
2. Ensure the cryostat is above 50 K.
3. Ensure the cryostat is connected to the He return panel, or that a non-return valve is fitted to the He outlet.
4. Fill the sample space with He by turning the blue 3-way valve to the left. Wait until the flow meter on the He return line registers flow again.

5. Remove the blanking flange and introduce the sample stick quickly but smoothly, ensuring that the sample is in the correct orientation.
6. Pump the sample space (*via* the 3-way valve turned to the right hand position) to ~1 mbar (the gauge on the top of the cryostat reads the sample space pressure) using the rotary pump.
7. Turn the 3-way valve to its left hand position to add He to the sample space, and pump again to about 1 mbar.
8. Add He to the sample space again and pump until the sample space gauge reads 20 mbar. This is the correct exchange gas pressure. Close the 3-way valve by returning to the vertical position.

4.3.3 Removing a sample

1. Ensure the cryostat temperature is greater than 50 K; at lower temperature any liquid helium that has been pulled through the capillary could boil rapidly; too high a temperature could cause He gas to diffuse through the Mylar window into the outer vacuum space.
2. Ensure the cryostat is connected to the He return panel, or that a non-return valve is fitted to the He outlet.
3. Close the valve to the pump on the capillary line.
4. Fill the sample space with He by turning blue 3-way valve to the left. Wait until the flowmeter on the He return line registers flow again.
5. Remove the sample stick quickly but smoothly by undoing the Klein flange. Cover the sample space with the blanking flange. Return the 3-way valve to its vertical position.
6. If the cryostat is to be left for a time without a sample present, pump the sample volume (*via* the 3-way valve, turned to the right hand position, using the rotary pump connected to the port above the valve).

4.3.4 Operation above 4.5 K

Operation above 4.5 K is fully automatic, the gas flow and heater output being controlled by the ITC503 temperature controller. The maximum temperature at which the cryostat can be operated is 300 K.

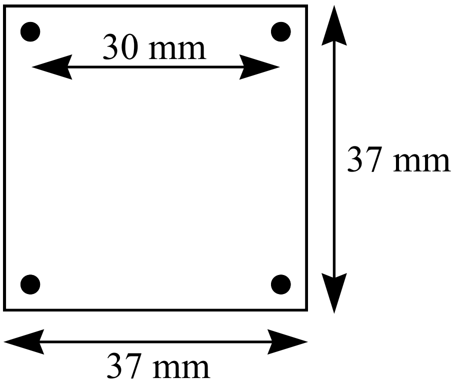
Be sure to issue the OpenGENIE command `blue_ht` and set a temperature above 4.5 K if moving from low temperature to high temperature operation.

4.3.5 Operation below 4.5 K

Because of limitations in the algorithm controlling the automatic needle valve in the ITC503 special action is required to operate below 4.5 K. To reach the base temperature (approximately 1.5 K) the following procedure should be followed.

To achieve stable temperatures below 4.2 K it is necessary to control the gas flow valve manually. Issue the command `blue_lt` in the OpenGENIE window and check that the gas flow control in the temperature window of SECI is showing 'Manual'. Connect the flow gauge attached to the Rootes pump frame to the exhaust and adjust the gas flow using SECI until the exhaust flow rate is around 450 cm^3/min. The temperature should drop rapidly. Small adjustments to the flow rate may be needed to ensure a stable temperature. Ensure that the temperature can be stabilized at the desired base temperature and disconnect the flow gauge to prevent it being clogged by oil. Set points can be set in the conventional manner up to around 5 K. To return to higher temperature operation the `blue_ht` command should be issued in OpenGENIE.

4.3.6 Sample holder



holes 3.1 mm diameter

The sample holder should be affixed to the sample blade at the bottom of the sample stick. The centre of the sample should be positioned 2 cm above the bottom of the sample blade. A small amount of grease should be placed between the sample plate and the blade to ensure good thermal contact. A silver mask should be used as appropriate to reduce the background.

4.4 Small flow cryostats

SECI Configuration Names: Flow_itc502.conf, Flow_itc503.conf

The temperature range is 4 to 400 K for the normal flow cryostat and 6 K – 600 K for the cryofurnace flow cryostat. Use the appropriate ITC5 temperature controller for the cryostat. Start pumping the OVC using a turbo pump.

A 5 mm spacer plate must be used with the flow cryostats! This is screwed to the top flange of the EMU cruciform before the cryostat is inserted.

4.4.1 Connections

Cryostat sample space port to a T-connector, which is connected to He gas, gauge and rotary pump. Cryostat heater/thermometer to ITC channel 1, the stick thermometer to ITC channel 2 (stick A) or 3 (stick B) and the transfer tube needle valve to ITC Aux. Out, through the patch panel. Transfer tube gas outlet (at the top of the dewar leg) to the pumping box *via* a long plastic tube.

4.4.2 Inserting the stick

The sample can be changed when the cryostat is cold, but heat it up to > 25 K first.

1. Let the sample space up to 1 atm with helium and remove the blanking plate.
2. Insert the stick: the pin on the stick flange locates into the hole in the flange on the cryostat.

3. Pump the sample space, purge with helium, repeat, and admit 15 mbar of exchange gas.

4.4.3 Cooling

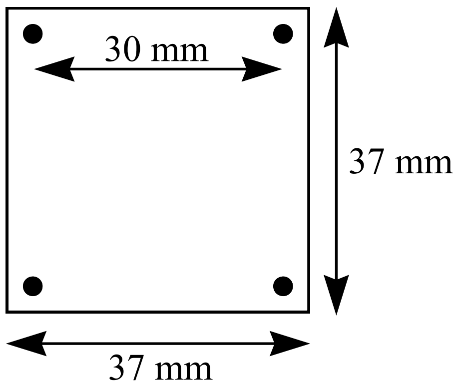
1. Check that the PTFE sealing washer is present on the cryostat end of the transfer tube.
2. Connect the needle valve cable. Turn the ITC5 off and on. This initialises the valve.
3. Fully open needle valve: press & hold "Gas Auto", then press "Raise", keep in Manual (light off).
4. Check with your local contact that the dewar has the helium level probe installed.
5. Insert the leg of the transfer tube in the dewar. Be very careful not to bend the transfer tube. In practice the tube will need to be almost fully inserted into the dewar before the transfer tube can be inserted into the cryostat.
6. Put the transfer tube into the cryostat and tighten the locking nut. Turn on the diaphragm pump. Open the valve on the pumping box if connected. There should be a very small flow.
7. After about 5 minutes the flow should increase as liquid reaches the cryostat, beginning cooling.
8. The green valve on the dewar should be open and the red valve closed during operation.
9. If the cryostat is still not cooling after 20 minutes, the tube may be blocked with ice or solid air:
10. Remove the transfer tube from the cryostat and dewar. Warm both ends with the hot air gun. Blow clean helium gas through it – use a piece of rubber tube over the cryostat end.

4.4.4 Removing the cryostat

1. Warm the cryostat to 25 K or above.
2. Ensure the needle valve on the transfer tube is open (set the ITC5 to Local, press Gas Flow and Raise) then shut the valve on the pumping box. The pressure should rise rapidly to 1 atm. If it doesn't, check with your local contact.
3. The transfer line can then be removed. Be careful not to bend either of the legs. If the cryostat will be used again during the experiment the transfer line may be left in the dewar with the needle valve closed. Be sure to fit the protective tube over the free end of the transfer line.
4. Unplug all electrical leads from the cryostat. Close the sample space tap and disconnect the sample space pumping line.
5. Close the OVC value and switch off and disconnect the turbo pump.
6. Remove the cryostat.

4.4.5 Sample holder

The flow cryostats use the same sample holder as those used with the Oxford Instruments Variox.



holes 3.1 mm diameter

4.5 Dilution Refrigerators

There are currently two dilution refrigerators that can be used on EMU:

4.5.1 The 'HiFi' Fridge

This is an Oxford Instruments dilution refrigerator insert in an Oxford Instruments Variox cryostat. The temperature range in dilution fridge mode is 50 mK – 4 K. Above this temperature, the cryostat can be operated as a normal variox.

4.5.2 The ICE Fridge

This fridge is currently under development.

Important – a 5 mm spacer plate must be screwed onto the top port of the EMU cruciform before this cryostat is mounted.

4.6 The Hotplate Furnace

SECI Configurations: Hotplate_furnace.conf

The muon furnace is designed to allow µSR experiments to be carried out on the EMU and MuSR spectrometers (with MuSR in either longitudinal or transverse orientation) at temperatures from room temperature up to 1000 K.

It consists of an outer vacuum jacket with a thin (30 µm) titanium window to allow muon entry, into which a centre stick is inserted which holds the sample and heating element. The sample temperature is monitored by a thermocouple sensor mounted on the sample plate, and controlled by a Eurotherm temperature controller; this in turn is monitored and controlled from SECI. The outer body of the furnace is cooled by water flowing through external pipes and around the muon entry window; two heat shields (also 30 µm Ti) between the entry window and the sample position further reduce heating effects on the furnace window.

For further details, please refer to the furnace manual: http://www.isis.stfc.ac.uk/groups/muons/muon-hotplate-and-optical-furnace-operation14715.pdf

It should be noted that Al sample holders are NOT suitable for use in the furnace owing to the low melting point of Al; similarly, Ag is unsuitable since silver plating of the sample often occurs even well below the melting point of Ag! Users should always consider whether their sample has a melting or decomposition temperature within the reach of the furnace and take suitable precautions.

Titanium produces a negligible depolarisation of the muon signal at furnace temperatures and so is suitable for use as a mask material. Thick windows in front of a sample should be avoided as the four titanium foils (including the one on the sample mount) greatly reduce the muon penetration. The range in the furnace is ~120 mg cm^{-2}.

NOTE: All set points and recorded temperatures are in °C NOT K.

4.6.1 Sample holder

The furnace mounting plate can take sample holders with maximum size 40 mm square and is drilled to allow EMU Variox cryostat holders to be fixed on to it. However, sample holders must not be made of aluminium (which melts within the furnace temperature range) and furnace users are advised to speak to their local contact regarding the best method of sample mounting.

4.7 The Reflector Furnace

SECI Configurations: Reflector_furnace_highT.conf, Reflector_furnace_lowT.conf

For further details, please refer to the furnace manual:

http://www.isis.stfc.ac.uk/groups/muons/muon-hotplate-and-optical-furnace-operation14715.pdf

4.7.1 Sample holder

Samples are generally mounted suspended from the thermocouple, in flypast. Small samples work best in this furnace. Please discuss with your local contact.

5 Magnetic Fields

5.1 Longitudinal magnetic fields

Longitudinal magnetic fields up to 4500 G are provided using Helmholtz coils, powered by the large Danfysik power supply. Fields of up to 5000 G can be used after discussion with your local contact. The supply is controlled from SECI, and in normal operation no manual intervention at the supply is required. The SECI command `lf0` selects this magnet power supply (danfysik) and subsequent `setmag` commands will adjust the field strength.

5.2 Transverse calibration fields

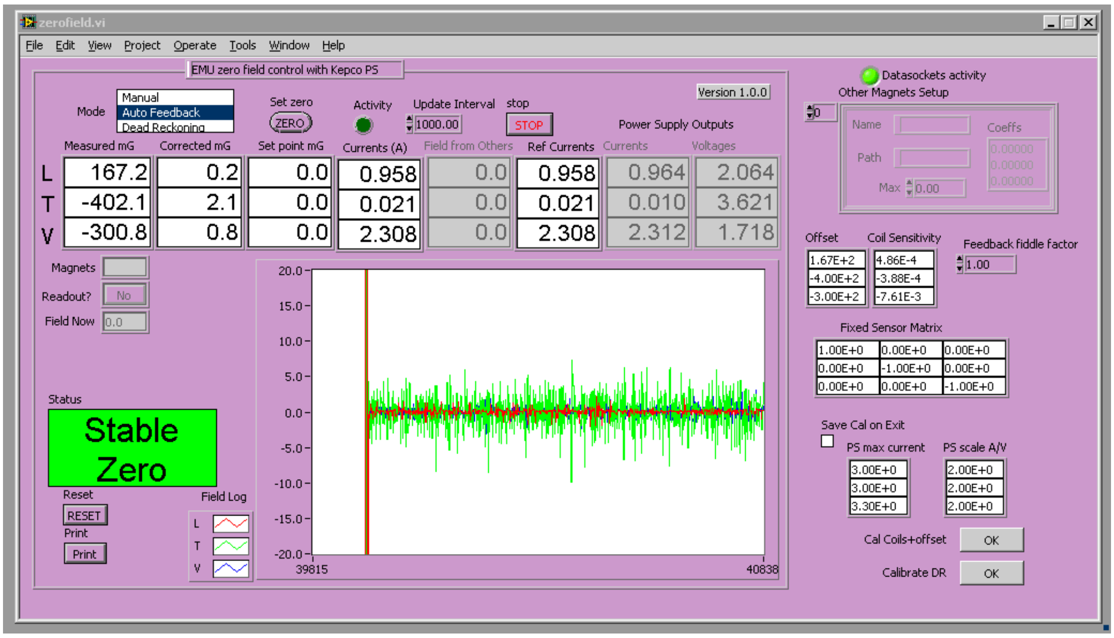
There are two saddle coils available that are capable of providing transverse fields of up to 150 G, and are therefore suitable for α calibration of longitudinal experiments. These are powered using the Farnell PSU located in the top of a rack adjacent to the Danfysik supply. The SECI command `tf20` selects this magnet power supply (calibrations) and subsequenet `setmag` commands will adjust the field strength.

5.3 Steering magnets

The muon beam can be steered by small amounts in the vertical direction to centre it on the sample. Particularly when small samples are being used, it is important to ensure the beam is steered correctly to maximise the fraction of muons hitting the sample. The vertical steering magnet is powered from the Farnell supply located in the rear part of the EMU cabin. Increasing the current in a negative sense moves the beam up with a sensitivity of approximately 4 mm/A, currents in excess of ±1.5 A should not be used and should not be necessary. This will usually have been performed by the instrument scientists prior to your experiment. Altering the beam steering will only be necessary in exceptional circumstances.

5.4 Zero field

There are three pairs of coils mounted on the instrument that are used to cancel the Earth's magnetic field. Issuing the command `f0` enables automatic compensation, using a fluxgate magnetometer mounted close to the sample position. When longitudinal `lf0` or transverse fields `tf20` are selected, the currents to the compensation coils are fixed at their optimal values.


zerofield.vi
File Edit View Project Operate Tools Window Help
EMU zero field control with Kepco PS
Version 1.0.0
Mode
Manual
Auto Feedback
Dead Reckoning
Set zero
ZERO
Activity
Update Interval
1000.00
stop
STOP
Power Supply Outputs
Measured mG
Corrected mG
Set point mG
Currents (A)
Field from Others
Ref Currents
Currents
Voltages
L
T
V
167.2
-402.1
-300.8
0.2
2.1
0.8
0.0
0.0
0.0
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2.308
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0.0
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0.021
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0.010
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2.064
3.621
1.718
Magnets
Readout?
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Field Now
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Status
Stable Zero
Reset
RESET
Print
Print
Field Log
L
T
V
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5.0
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-10.0
-15.0
-20.0
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40838
Datasockets activity
Other Magnets Setup
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Name
Path
Max
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Coeffs
0.00000
0.00000
0.00000
Offset
Coil Sensitivity
Feedback fiddle factor
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-4.00E+2
-3.00E+2
4.86E-4
-3.88E-4
-7.61E-3
1.00
Fixed Sensor Matrix
1.00E+0
0.00E+0
0.00E+0
0.00E+0
-1.00E+0
0.00E+0
0.00E+0
0.00E+0
-1.00E+0
Save Cal on Exit
PS max current
PS scale A/V
3.00E+0
3.00E+0
3.30E+0
2.00E+0
2.00E+0
2.00E+0
Cal Coils+offset
OK
Calibrate DR
OK

6 Computing

6.1 Computer access

A number of computers are available for use by EMU users:

- NDXEMU is the data acquisition computer and is on the right hand side of the cabin. This should not be used for data analysis. This computer is mirrored on the screen on the platform by the instrument.
- A PC (NDLEMU) is available in the cabin for data analysis. This computer is found on the left hand side of the cabin. Please be aware before carrying out any confidential work on this computer, that it may be accessed remotely.

6.1.1 Logging into the EMU data acquisition computer

To start a session:

- **Login to workstation as user EMU**

  NDXEMU is the computer which runs the data acquisition and sample environment through the SECI panel. This is a rack mount computer in the counting room. The control computer you use to access SECI does so through a remote desktop.

  To open SECI ensure that no programs are running on the control PC. Click on NDXEMU remote desktop icon on the left of the screen – the required login and password can be found on the whiteboard in the instrument cabin. (If you already have access to NDXEMU the screen is grey). To start SECI select SECI User interface from the start menu. Instructions on how to use SECI are given in section 7.

6.2 Monitoring your experiment

If you are away from the experimental hall, the ISIS beam current and MCR messages are available at http://www.isis.rl.ac.uk/status/

There are also screens showing the beam current at other locations on site, for example the R1 and R22 Coffee Lounges.

The "dashboard" showing the status of the instrument and run in progress is available on the web at http://dataweb.isis.rl.ac.uk/ Select "EMU" from the list of instruments.

6.3 Accessing data

Raw data is accessible on the internal network at:

\\isis\inst$\NDXEMU\Instrument\Data\cycle_yy_c\EMU12345678.nxs.

And also:

\\emu\data\EMU12345678.nxs.

(data from previous ISIS cycles will be archived to:

\\emu\data\cycle_yy_c\EMU00000123.nxs).

From outside ISIS, data can be downloaded *via* the ISIS ICAT data catalogue: http://www.isis.stfc.ac.uk/groups/computing/data/icat11680.html

You will need your STFC Federal User ID and password. This is the one that the User Office will have given you in order to complete your experimental risk assessment and user registration. People who were not on the experimental team may not be given access – if you think you should be granted access ask your local contact.

A local copy of the data currently being measured is stored in \\emu\data; this updates every 5000 frames and can be accessed by data analysis programs.

6.4 Data Analysis

There are a number of software packages that can be used to analyse μSR data from EMU. Two that are supported at ISIS are Mantid and WiMDA.

6.4.1 Mantid

This is installed on the analysis PC NDLEMU, and also available for download from http://www.mantidproject.org, where further information about the program is also available. This program is currently being developed but current features include fitting to time domain data and algorithms for analysis of level crossing and RF resonance curves are available. The manual 'Mantid for μ^+' is available on the ISIS Muon web pages:

http://www.isis.stfc.ac.uk/groups/muons/muons3385.html.

6.4.2 WiMDA

This is installed on the analysis PC NDLEMU, and also available for download from the ISIS Muon web pages if you want to run it on your own laptop (http://www.isis.stfc.ac.uk/groups/muons/downloads/downloads4612.html). Loading run 0 will load the run currently in progress.

6.5 Connecting a laptop computer

When you arrive at ISIS you should be given a coupon providing the connection details to the wireless internet at RAL. If this has not happened you should speak to your local contact. This is the preferred method of connecting while on site and should be the simplest to use. Access is also possible through the eduroam network.

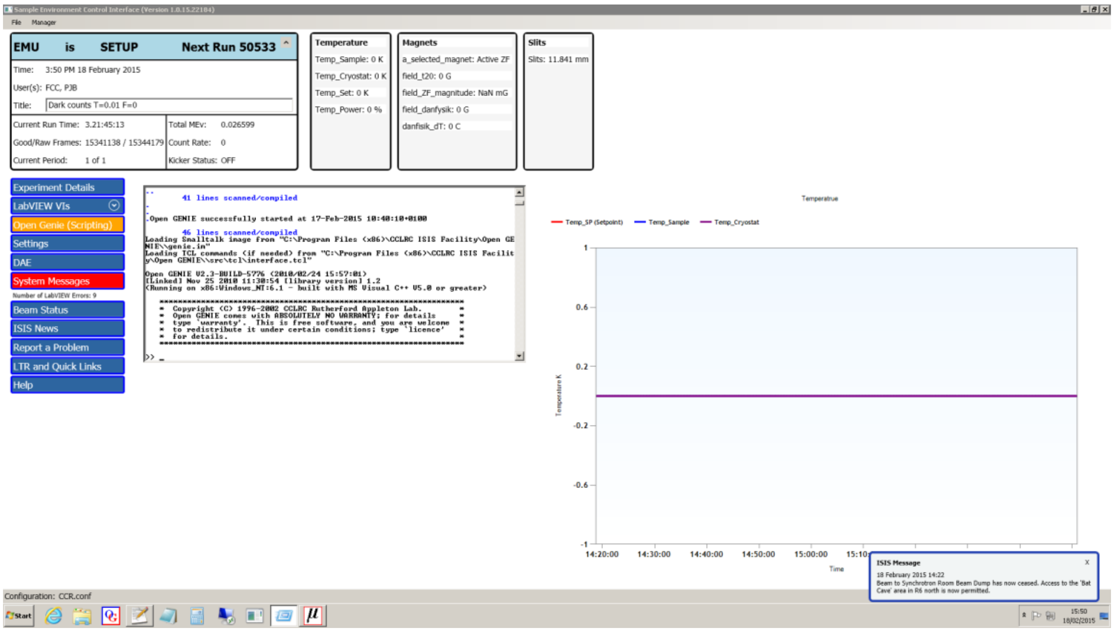
The wireless internet reception in the EMU cabin is not always adequate so cable connections to the internet are also available. Speak to your local contact if you think that you might need this and have any difficulties in setting it up. It is likely that you will need to change the proxy configuration of your internet connection. The automatic proxy configuration URL is: http://wwwcache.rl.ac.uk/proxy.pac.

6.6 Printers

A colour printer is situated inside the MuSR cabin (R55-MUSR), and this is available from any PC.

7 SECI

SECI is the program that is run on EMU to control the collection of data and the sample environment for the EMU instrument. All commands should be entered into the Open Genie terminal on the SECI dashboard.



7.1 Running SECI

7.1.1 Starting SECI

SECI must run from the EMU account on the NDXEMU workstation (see section 6.1. for logging in). It is possible to run an experiment using only a small number of commands; these are all typed in the Open Genie window located in the dashboard. Commands are not case sensitive.

7.1.2 Changing configurations:

Every time the sample environment is changed (including sample sticks) the appropriate configurations must be opened.

- Select Open from the File menu of the ISIS SECI window.
- Select correct configuration (please do not save configurations).
- SECI should restart with the correct VI's.

7.1.3 Common SECI commands

Starting a run

Type `begin`

Ending a run and saving the data

Type `end`

Ending a run **without saving**

Type `abort`

Pausing a run

Type `pause`

Then to **continue** the run

Type `resume`

Setting a **temperature** (of *value* K)

Type `settemp` *`value`*

Setting a **field** (of *value* G)

Type `setmag` *`value`*

Setting the **slit** position

Type `slits` *`value`*

Selecting **T20** power supply and setting 20 Gauss

Type `tf20`

Selecting **Danfysik** power supply

Type `lf0`

Selecting **auto-zerofield**

Type `f0`

Waiting for *value* seconds

Type `sleep` *`value`*

Setting the **label**

Type `setlabel` /qualifier

- `/s` for sample
- `/c` for comment
- `/u` for user
- `/rb` for rb number
- `/t` for temperature
- `/f` for field
- `/g` for geometry
- `/o` for orientation

You will be prompted for information.

Displaying all **control blocks**

Type `cshow/all`

7.1.4 Blue Cryostat

For operation **below 5K**

Type `blue_lt`

For operation **above 5K**

Type `blue_ht`

7.1.5 Temperature parameter files

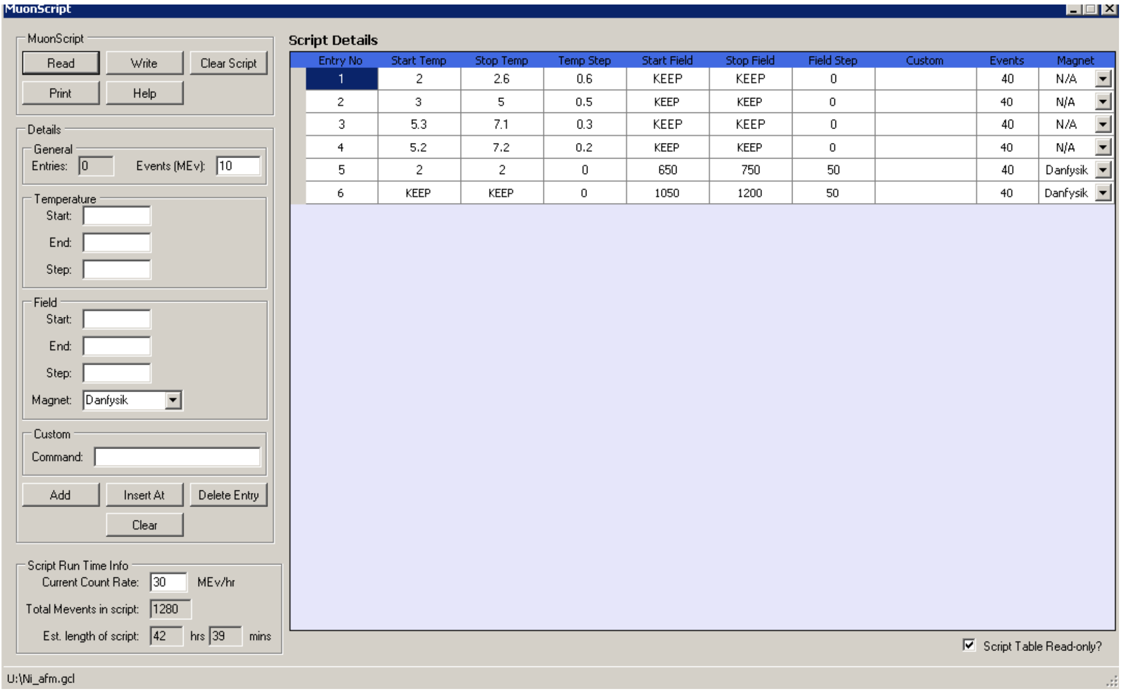
When a configuration is selected, the appropriate tpar file is copied into the working directory: "C:\labview modules\mkscript3" directory and is called "muon_temperature.tpar". Any changes made to this file are only saved until a new configuration file is loaded.

7.1.6 Stopping SECI

On NDXEMU, if SECI is responding then under file option select exit or select KILLSECI on the start menu.

7.2 Script Writing

We use a program 'MuonScript' to generate a script from a table of fields, temperatures and run lengths. A new script can be edited while a previous run, or script, is still in progress. MuonScript is started along with SECI but is not part of it. Select it from the Windows task bar at the bottom.



'Read' – Opens a previously saved script for editing and reuse. To edit, ensure that the 'Script Table Read-only?' checkbox in the bottom right hand corner is unchecked.

'Write' – Allows the current script to be saved. Save scripts in the default directory (u:\), without spaces in the filename.

'Clear Script' – Empties the current contents of the script window.

'Print' – Prints the script.

'Help' – Accesses help.

To add an entry to the script table, type in the required temperature, field (selecting 'Danfysik' for the main longitudinal field or 'Calibration' for the transverse field) and number of million events (MEv), into the boxes on the left and then click 'Add'. This appends the line to the end of the script table.

If no change is required, leave the temperature and/or field values blank (KEEP will be shown in the script table), instead of re-entering the same value (this avoids having to wait to confirm the value is still stable).

The first entry in the script table can take control of, and end, a run that was in progress when the script starts. In this KEEP the current temperature and field, only selecting the number of million events at which the present run should finish.

For a linear scan of either temperature or field (but not both), enter the start, end and step values. Use only the Start value for a single run. Scans can go up or down.

To insert a line above one currently in the script table, highlight that entry in the table, then click 'Insert At'. 'Delete' removes the highlighted entry. 'Clear' clears the entire script table.

To estimate the counting time taken by a script, enter the current count rate in the box at the bottom left, and MkScript will calculate the total counts in the script and the estimated time. This does not include time for temperature or field changes which may be significant. (To update the estimated time after changing the rate, add another entry, or click somewhere in the table.)

To **load a script**, open the OpenGENIE window:

Type `load "u:/`*`yourscriptname`*`.gcl"`

To **run** the loaded script

Type `runscript`

To **end** a script

Type `<ctrl>c`

This ends the script, but any run currently under progress will continue, and can be ended in the normal way by typing `end` into the OpenGENIE window.

8 The Beamline and the Spectrometer

The results presented in this chapter are intended only as a guide. If a measurement is of particular importance to the outcome of an experiment the appropriate calibration should be made.

8.1 Detectors

The EMU spectrometer has 96 detectors. There are a total of 6 axial rings, 3 forward of the sample position and 3 backward. Each axial ring has the same solid angle. Radially there are 16 detectors in each ring.

The detectors are numbered as follows:

Forward detector bank: The rings are numbered along the axial direction of the beam as they are constructed in groups of three. The rings are mirrors of each other with the numbers increasing sequentially clockwise from the central detector.

Outer ring (closest to the sample): 1, 4, 7, 10, 13, 16, 19, 22, 25, 28, 31, 34, 37, 40, 43, 46.

Middle ring: 2, 5, 8, 11, 14, 17, 20, 23, 26, 29, 32, 35, 38, 41, 44, 47.

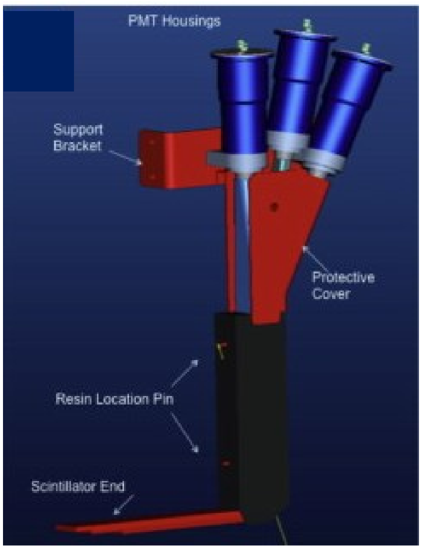
Inner ring (furthest from the sample): 3, 6, 9, 12, 15, 18, 21, 24, 27, 30, 33, 36, 39, 42, 45, 48.

Backward detector bank:

Outer ring (closest to the sample): 49, 52, 55, 58, 61, 64, 67, 70, 73, 76, 79, 82, 85, 88, 91, 94.

Middle ring: 50, 53, 56, 59, 62, 65, 68, 71, 74, 77, 80, 83, 86, 89, 92, 95.

Inner ring (furthest from the sample): 51, 54, 57, 60, 63, 66, 69, 72, 75, 78, 81, 84, 87, 90, 93, 96.



8.1.1 Mantid

Data from individual rings can be analysed by choosing the grouping file 'EMU_rings_96.xml'.

The default grouping file is 'EMU_Detector_Grouping_LF_96.xml', which groups together the three forward and three backward rings respectively.

8.1.2 WiMDA

Using WiMDA, the grouping menu allows the data from all the detectors to be accessed individually, in rings (32 detectors in each ring), combinations of rings or all simultaneously.

8.2 The slits, beam spot size and count rate

8.2.1 Beam spot size and slit setting

The uncollimated muon spot is elliptical with its major axis in the horizontal direction. The uncollimated beam spot size is ~25 × 10 mm^2 at the sample position. Horizontal collimation of the beam is achieved using a set of remote slits, which are controlled by SECI using the `slits` command in OpenGENIE. Vertical collimation is not provided.

The muon spot size (in the EMU CCR) has been measured for various slit settings by masking a large haematite sample (used to rapidly depolarise implanted muons) with a silver mask. Using a 100 G transverse field, the amplitude of the oscillating signal indicates the fraction of the beam falling on the mask (full asymmetry was measured using a large silver plate).

	Slit setting					
	4	8	12	16	20	30
% of beam on a 20 mm mask	21 %	24 %	30 %	38 %	45 %	60 %

It is very important to remember that these results only apply to the EMU CCR. The muon spot size is appreciably larger in both the furnace and the cryostats where the muons are scattered by the windows.

8.2.2 Event rate and slit setting

The table presented below shows the event rate as a function of slit width for a 20 mm silver mask over haematite mounted on the EMU CCR. Other sample environment equipment will show lower rates owing to thicker 'tails' acting as a positron degrader. This is especially true for the furnace, where the measured rate is typically two thirds that of the CCR.

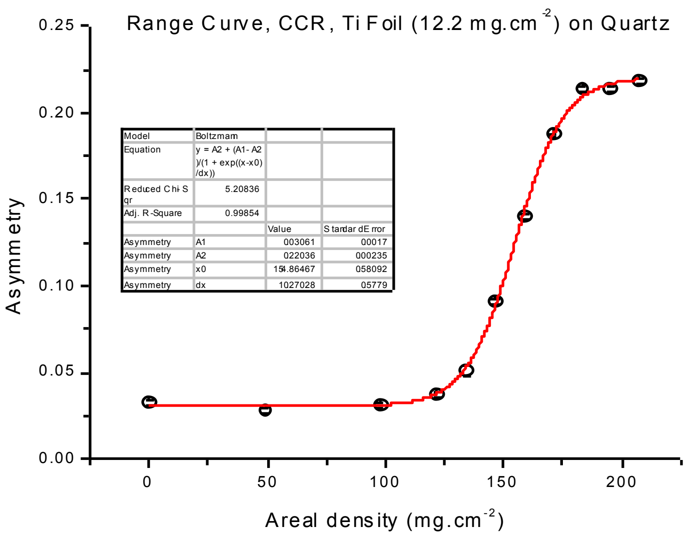
Slit setting	4	8	12	16	20	30	40	60	80
Rate (Mev/hr)	40	72	100	129	155	218	263	318	350

In addition to controlling the muon spot size, the slits can be used to regulate the event rate and thereby control the distortion at the start of histograms due to detector 'dead time' effects. Although the effect is particularly evident at high event rates, some distortion is always present. Because various parts of the detector have limitations on the speed with which they can respond there is a 'dead time', τ_d, after each event during which further positron decays are missed. The effect of this 'dead time' can be modelled and the reduced rate observed in the experiment, r_{ob}, is found to be related to the true rate, r, by the expression $r_{ob} = r/(1+r\tau_d)$. At rates < 100 Mev/hr (shown green in the above table), distortion is unlikely to be seen for typical runs. At rates up to 160 Mev/hr (shown as amber), distortion may be observed, but can be corrected using data Mantid or WiMDA. At rates > 160 Mev/hr (shown in red), other effects come into play and the data collected in typical runs can no longer be corrected. Users should therefore always consider using the facilities provided by both Mantid and WiMDA to correct for this effect when analysing data.

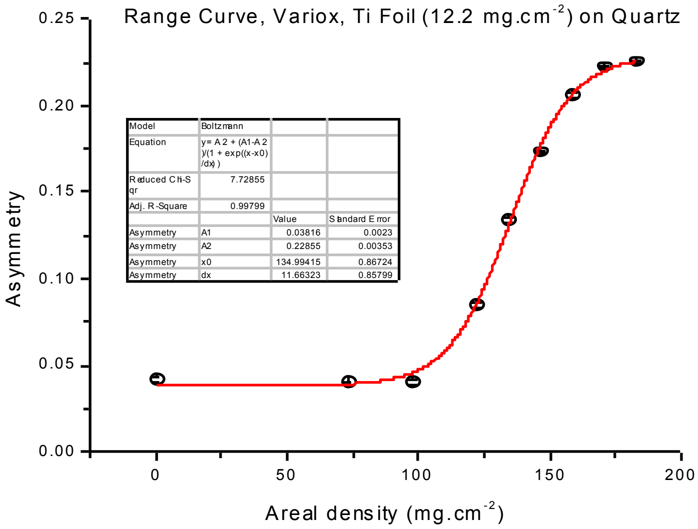
Event rates of ~100 Mev/hr are a good compromise between visible dead time distortion at very high rates and inefficient use of beam time. It should be noted that the 'figure of merit' for an experiment is given by (sample_asymmetry^2 × rate), so small changes in the fraction of beam on the sample and hence the sample asymmetry can be significant.

8.3 Range curves

The muons in the beam hit the front surface of the sample at about $0.25c$ and are then slowed by interactions with the material before stopping. The muon beamlines were retuned in March 2015, resulting in higher momentum muons, with a greater range. The range curves shown below were measured after this momentum increase to allow for the increased range The plot shown below measures the diamagnetic asymmetry (in a 100 G transverse field) as thin titanium foils (25 µm, 12.2 mg/cm^2) are added in front of a thick quartz plate mounted in the CCR (without the can). Initially a low asymmetry is recorded as all muons are stopped in the quartz where there is an appreciable muonium fraction. Adding more than ten titanium foils the asymmetry rises as an increasing proportion of the muons are stopped in the metal (in which all muons thermalise into a diamagnetic state). Full asymmetry is obtained when at least fifteen foils have been added.



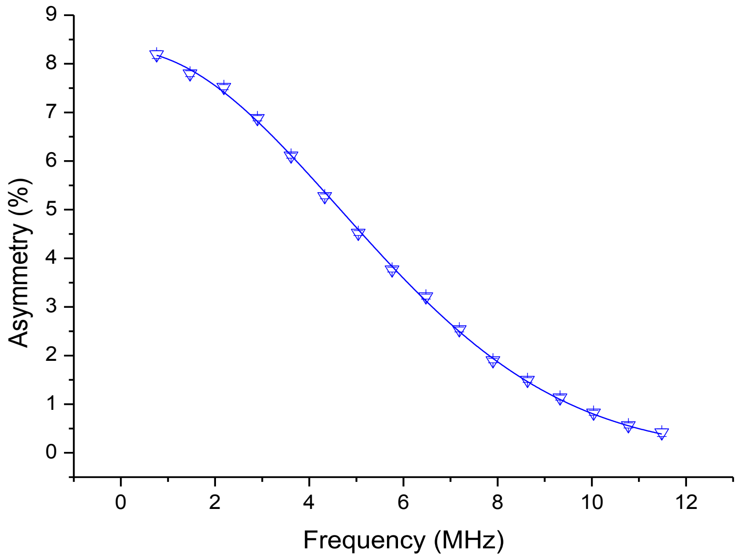
The plot shown below measures the diamagnetic asymmetry (in a 100 G transverse field) as thin titanium foils (25 μm, 12.2 mg/cm^2) are added in front of a thick quartz plate mounted in the EMU Variox cryostat. The asymmetry starts to rise after 8 foils have been added and at least fourteen foils need to be added for full asymmetry to be obtained.



Samples should be appreciably thicker than the measured range since the exact form of the curve depends upon the material. If this is not the case, a check should be made by adding thin sheets of metal or plastic in front of the sample to maximise the signal from the sample. The decision to use either metal or plastic as the degrader will generally depend upon the nature of the sample being studied and the need to create a contrasting signal from the sample and degrader. For samples having a missing fraction, metal is the most appropriate choice (pre-cut titanium sheets are available for this purpose) while, conversely, a plastic degrader is ideal for metallic samples.

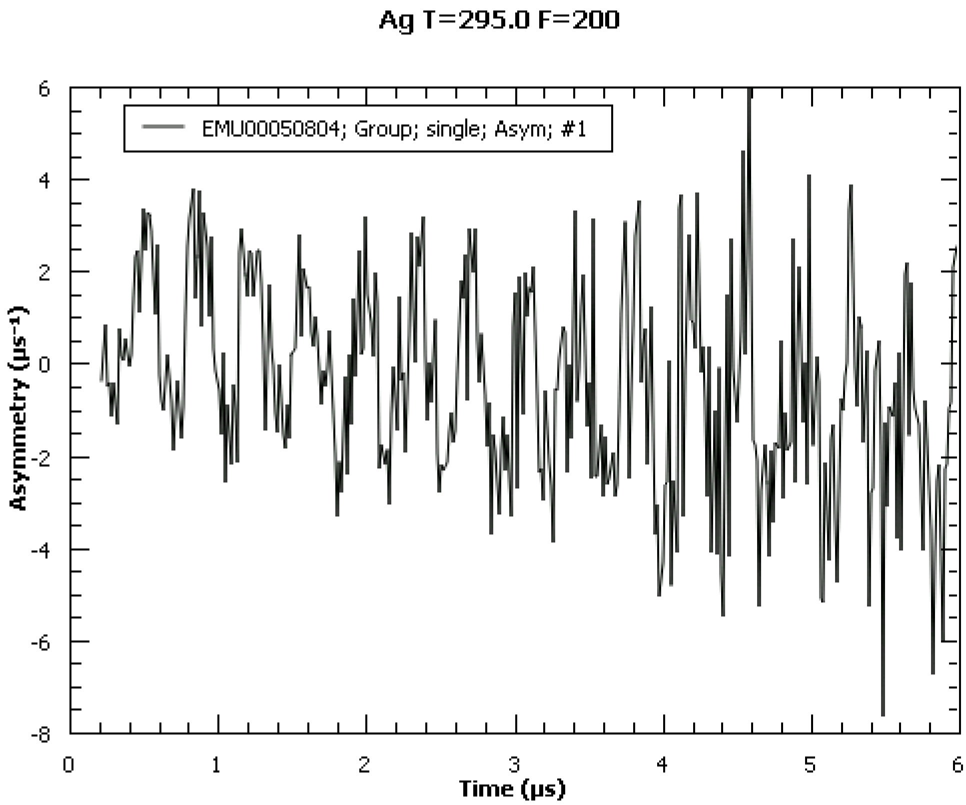
8.4 The muon pulse width and the frequency response

At ISIS the muons are produced in large numbers in short pulses (about 80 ns wide at half height) and the approximation is usually made that an average arrival time near the centre of the muon pulse can be used as time-zero. This is adequate if the time-scale of the evolution of the muon polarisation is long compared to the width of the muon pulse but leads to difficulties in cases where the evolution is rapid. The effect is seen clearly by considering a transverse field experiment performed at a succession of magnetic fields. At low fields the frequency is small and the polarisation precesses with full asymmetry. As the field increases there is an appreciable phase difference developed between muons from the beginning and end of the pulse and the observed asymmetry falls. This frequency response has been measured by observing the precession of muonium in quartz in small transverse fields, the results are shown below. The curve below shows the frequency response measured in April 2015, after the initial phase of the muon beamline upgrade.

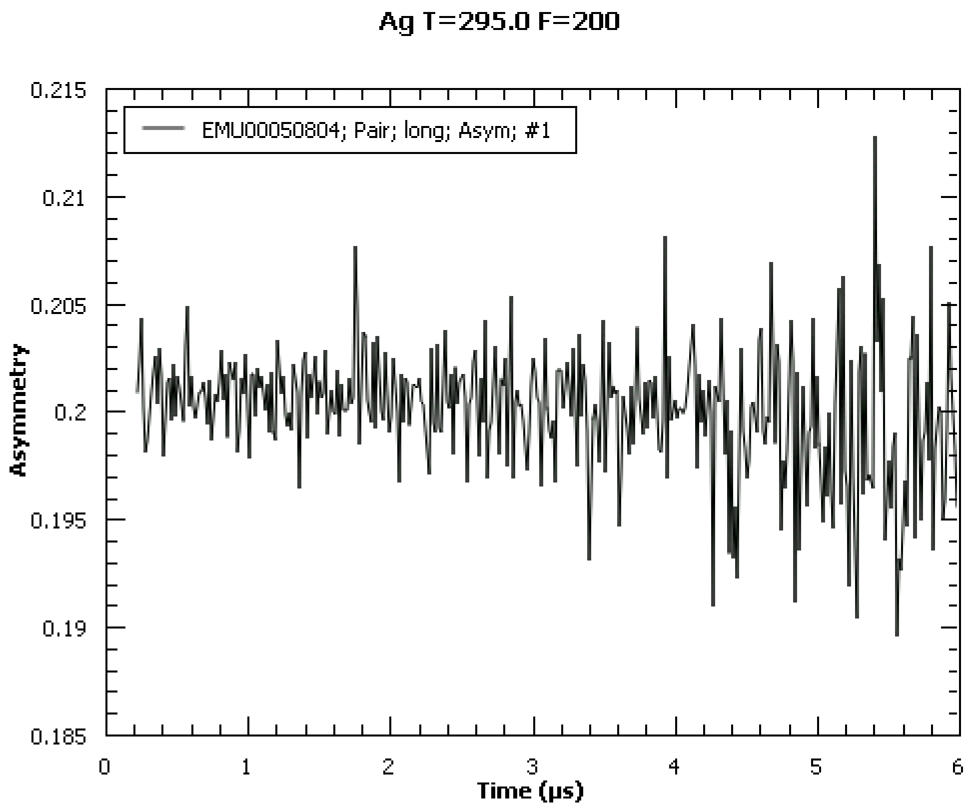


8.5 Spin rotation by beam line components

When the muon beam is deflected by a magnetic field the spin and momentum vectors remain collinear. The same is not true if the beam is passed through an electric field, in this case the muon spin is rotated with respect to its momentum vector. In transport from the muon production target to the EMU spectrometer the beam traverses two regions of electric field, namely the separator and the kicker, and there is a combined spin rotation of approximately 7° pointing upwards from the direction of travel. This rotation is best observed by examining individual detectors for data taken in small longitudinal fields (up to ≈ 400 G); under these circumstances there is a precession of the muon spin in the field and an oscillating signal can usually be seen (see figure below).



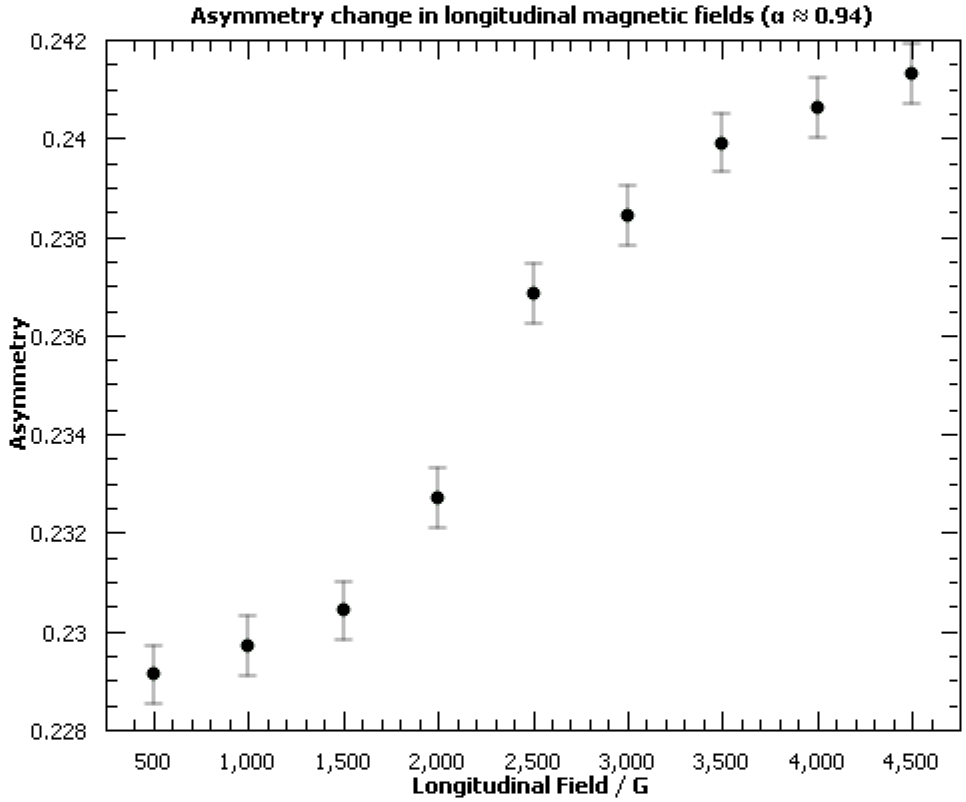
Grouping the detectors, however, the effect is removed (as shown below) by the subtraction of the backward histograms from the forward set and analysis can proceed as normal.



8.6 Measurements in high magnetic fields

The asymmetry measured for a large silver plate, mounted on the EMU CCR, in longitudinal magnetic fields up to 0.45 T is shown below. As the field is increased there is a gradual increase in the measured asymmetry, with roughly a 5 % increase at 0.45 T. This change is an artefact that is probably a result of a shift in the value of α caused by the interaction of the magnetic field with both the decay positrons and the photomultiplier tubes.

The data presented was measured using an experimental set-up with a value of α close to one in low magnetic fields.



In general, for different initial α values different results will be obtained. If possible, the exact shape of the curve should be determined experimentally using a silver plate mounted to have approximately the same value of α as that measured during the experiment.

8.7 Flypast

The flypast capabilities of EMU were greatly improved with the instrument upgrade. Tests on 4 × 4 mm pieces of Ag and Cu in the CCR in flypast mode show that such small samples can be run, and the data analysed using all the detectors rings.

Ag sample – in the 4 × 4 mm sample, the muon hopping can be seen at 125 K. This requires long tail stability because the relaxation is in the order of 0.008 μs^{-1}.

Cu sample – the behaviour of the 4 × 4 mm sample, when analysing all the rings, was identical to a 4 × 4 cm plate. The Kubo-Toyabe like behaviour can be seen in all the rings with the same sigma as observed in the bulk.

9 Troubleshooting

9.1 No muons

- Check the ISIS accelerator is running at a reasonable rate. The display in the hall provides a readout of the pulse intensity in μA and indicates when the beam is off. If the display shows 5 μA, the machine is probably at base rate (i.e. $\frac{1}{32} \times 50\text{Hz}$) and the updates of the histograms collected by the computer will be correspondingly slower (typically 50 minutes!).
- **Check the beam blocker is raised: the gate must be closed and locked to allow this.** The blue interlock lights in the EMU area will only be on if the blocker is raised.
- Check the 'BEAM OFF' button on the fence in the zone is not pressed. Release it then restart the bending magnet power supply (see section 9.6) using only the 'START' button.
- Check that all the beam line magnets are working (see section 9.6). If the count rate is zero and the MuSR spectrometer is running normally the Septum magnet '14' may have tripped.
- Check that the photomultiplier tubes are powered. The supply is located in the back of the EMU cabin (bottom of right hand rack), and there should be an illuminated 'HV ON' sign.
- Check the kicker is working. If the kicker has tripped the count rate will be very small (but usually not zero) and there will be a light flashing at the back of the MuSR cabin.
- If the rate is fluctuating check the separator is working reliably, it should hold the set voltage (typically 90 kV) for long periods without tripping.

9.2 Computer

If SECI crashes go to the start menu on NDXEMU and click on the KILLSECI.cmd. Once SECI has closed wait a few minutes and then restart SECI, this should enable full control of the spectrometer.

9.3 Spectrometer magnets

If there is no communication between SECI and the selected magnet power supply the following procedure may rectify the situation:

- Set the DUMMY magnet device by typing `F0`.
- Then try restarting the magnets by issuing the commands `TF20` of `LF0`.
- If neither of these work restart SECI.

9.4 Temperature control

SECI controls the temperature *via* labview. For temperature control the correct configuration must be loaded for the specific sample environment. Ensure that this is the case. If communication is lost restart SECI

9.5 Resetting the kicker

The kicker can be accessed *via* the stairs at the back of the muon platform area. Instructions on how to reset the kicker are posted on the side of the control panel.

9.6 The beamline magnets

Located at intervals along the muon beamline between the production target and the spectrometer are dipole and quadrupole magnets which respectively act to steer and focus the muon beam. Most of these magnets are located before the kicker, and therefore any faults will affect all three muon beam lines. However, following the kicker there is a septum magnet and three quadrupole magnets specifically for EMU, and these should be checked if a problem with the beam in the EMU arm is suspected. The power supplies for all of these magnets are located on the raised platform on the East side of the experimental hall (the steps up to this are opposite the steps taking you over the proton beam to the other side of the hall). The normal working currents for these supplies are indicated on them, but call your local contact if you think there is a fault.

10 Contact Points

10.1 Laboratory

ISIS Neutron & Muon Source
STFC Rutherford Appleton Laboratory,
Harwell Oxford,
Didcot,
Oxfordshire,
OX11 0QX. ☎ (01235) 821900 (national)
☎ +44 1235 821900 (international)

Main control room (MCR)................☎6789
Site Emergency ....☎2222 (01235 778888 from outside the lab)
EMU cabin (R55)..............................☎6831
MuSR cabin (R55) ....☎6135
HiFi cabin (R55) ....☎6851
Argus / RIKEN ....☎6766
Health Physics / Sample checking .....☎6696
Computer support..............................☎1763 (07770 858090 from outside the lab)
ISIS User Office................................☎5592
Ridgeway House ....☎5500
Cosener's House ....☎3007 or (01235) 523198
Taxi ....☎5592 (during the night ring the MCR)

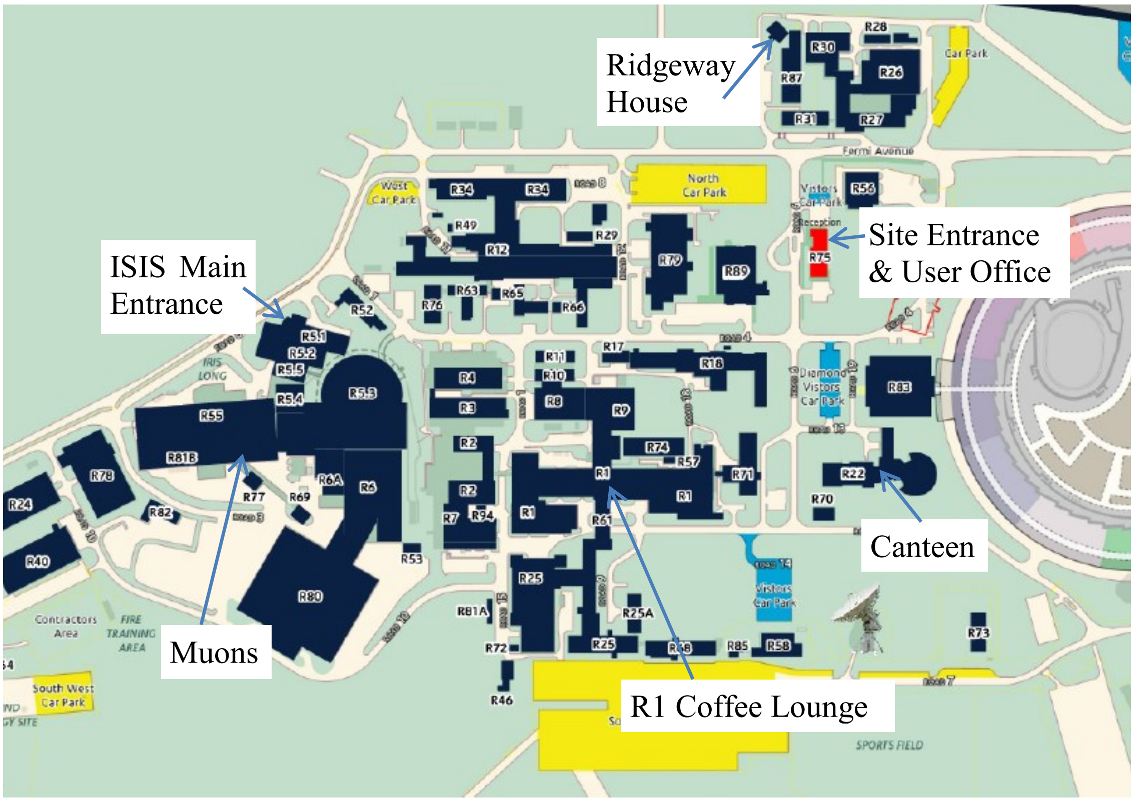
From outside the laboratory certain extensions may be direct dialled, the number being formed in the following manner:
(01235) 44*xxxx*, where '*xxxx*' is the required extension.

To call offsite: provided the number starts with a '0', simply dial the number, otherwise prefix the number by '9'.

Up to date contact details for instrument scientists can be found on the muon group website:

http://www.isis.stfc.ac.uk/groups/muons/muons3385.html

10.2 Site Map



10.3 Catering

Breakfast for users staying in Ridgeway House is available there. Breakfasts, lunches, and dinners are served in the R22 cafeteria. Light lunches and snacks are also available in the R1 coffee lounge. Vending machines are situated in the User Lounge in the Experimental Hall (R5.5), next to the entry to the hall from the Main Control Room.

Opening times are listed on the ISIS User Office website: http://www.isis.stfc.ac.uk/user-office/refreshments4424.html.

10.4 Publications

Further information about the EMU instrument can be found in the following paper:

Optimising a muon spectrometer for measurements at the ISIS pulsed muon source. S. R. Giblin *et al.*, Nucl. Inst. Meth. **A751** 70–78 (2014) http://dx.doi.org/10.1016/j.nima.2014.03.010.

For further information on the ISIS muon beam lines see, for example:

Fast E-Field switching of a pulsed surface muon beam: the commissioning of the European muon facility at ISIS. G.H. Eaton *et al*. Nucl. Inst. Meth. **A342**, 319-331, 1994. http://dx.doi.org/10.1016/0168-9002(94)90257-7

The ISIS muon group web pages contain information on the muon facility, including the current instrument schedules, the address is

http://www.isis.stfc.ac.uk/groups/muons/muons3385.html.

10.5 Local information

Transport	
National Rail Enquiries	08457 48 49 50 or http://www.nationalrail.co.uk/
Thames Travel Oxford city, Didcot and rural bus services (including routes X1, X32 & X34) that pass the lab.	01865 785400 http://www.thames-travel.co.uk/
Oxford Bus Company Oxford city local buses and coaches to London (X90), Heathrow and Gatwick.	01865 785400 http://www.oxfordbus.co.uk/
Stagecoach Oxford Oxford city bus services (including route 34) that pass the lab and Oxford – London express service.	01865 772250 http://www.stagecoachbus.com/localdefault.aspx?Tag=Oxford

Bus services depart from the Harwell Campus bus station that is located a short distance beyond the Rutherford Main Gate (ask for directions). It takes around 15 minutes to walk from the ISIS experimental hall (R55) to the bus station. Live timetables for buses to Didcot, Oxford and Wantage can be found at http://www.oxontime.com/.

BAA Flight Information Arrival information for many UK airports including Heathrow and Gatwick.	http://www.baa.com
General Information Oxford Tourist Information Centre	http://www.visitoxfordandoxfordshire.com/

Eating and Drinking

Indian Dreams, 32 Wantage Rd, Didcot	OX11 0BT	01235 817711
Kolkata, 222 Broadway, Didcot	OX11 8RS	01235 812206
Sunkoshi Tandoori, 226a Broadway, Didcot	OX11 8RS	01235 813573
Prezzo Italian Restaurant, 6 Market Place, Didcot	OX11 7LE	01235 511271
Wildwood Kitchen, 8 Station Road, Didcot	OX11 7LL	01235 519968
Cherry Tree Inn, Steventon	OX13 6RZ	01235 831222
The Fish, Sutton Courtenay	OX14 4NQ	01235 848242
Fleur de Lys, East Hagbourne	OX11 9LN	01235 813247
The George and Dragon, Sutton Courtenay	OX14 4NJ	01235 848142
The Harrow, West Ilsley	RG20 7AR	01635 281260
The Hart of Harwell, Harwell	OX11 0EH	01235 834511
The Plough, Sutton Courtenay	OX14 4AT	01235 848801
The Prince of Wales, Didcot	OX11 7NN	01235 511888
Rose and Crown, Chilton	OX11 0RZ	01235 862992
The Swan Inn, Sutton Courtenay	OX14 4AE	01235 847446
The Wheatsheaf Inn, East Hendred	OX12 8JN	01235 833229