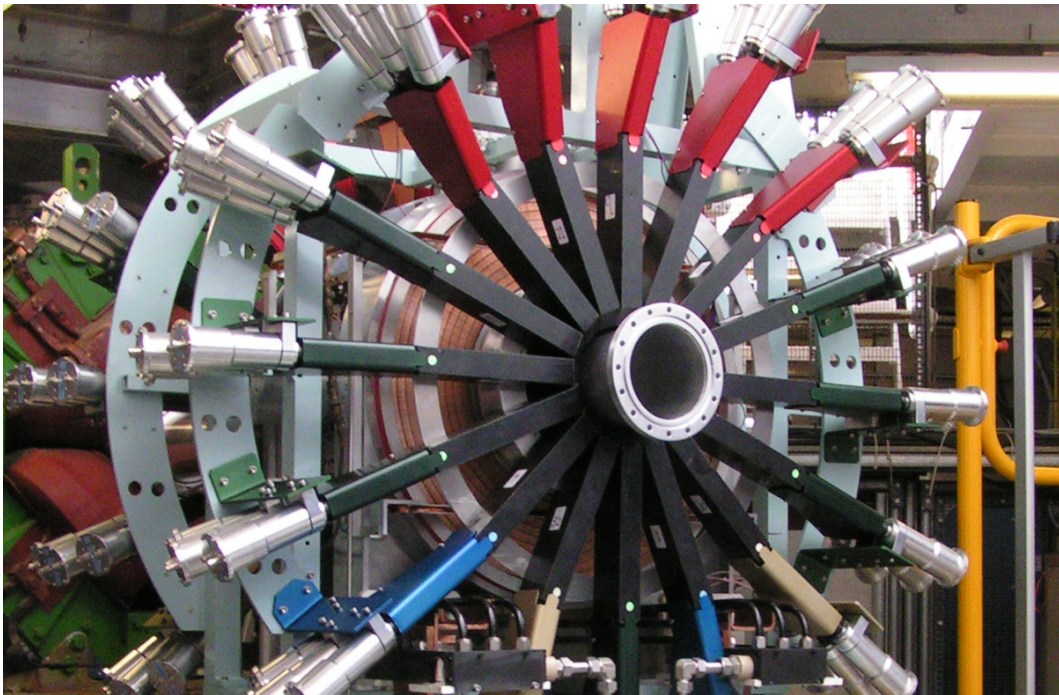


EMU User Guide



Updated on March 2021

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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. A small power supply for the main magnet coil is also available, which allows one to set a longitudinal field (up to 250 G) with a better accuracy. 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 or IBEX program, monitoring the progress of the experiment, and carrying out data analysis. Samples should be mounted in the prep lab (R55 South-side sample 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 “Work in Progress” forms kept in the lab door, and all equipment used should be tidied away when finished.

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](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:

<https://www.isis.stfc.ac.uk/Pages/Muons.aspx>

1.1 The Facility and EMU Spectrometer

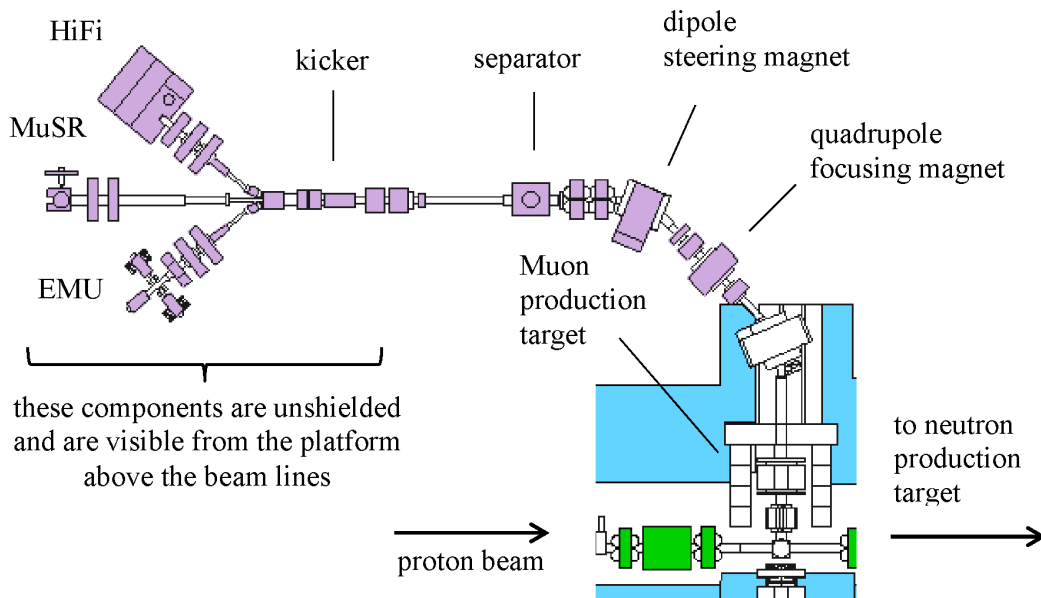


Figure 1: General layout of the European Muon Facility at ISIS

Fig. 1 shows the general arrangement 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 focusing and steering of the muon beam will have been checked during the calibration period at the start of each ISIS cycle by instrument scientists. If a change to the focusing 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.

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 for a lower background.
- 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 calibrations and measurements.
- The instrument control program, SECI (or IBEX), is set up with a proper .conf file.

2.2 Operating the EMU area interlocks

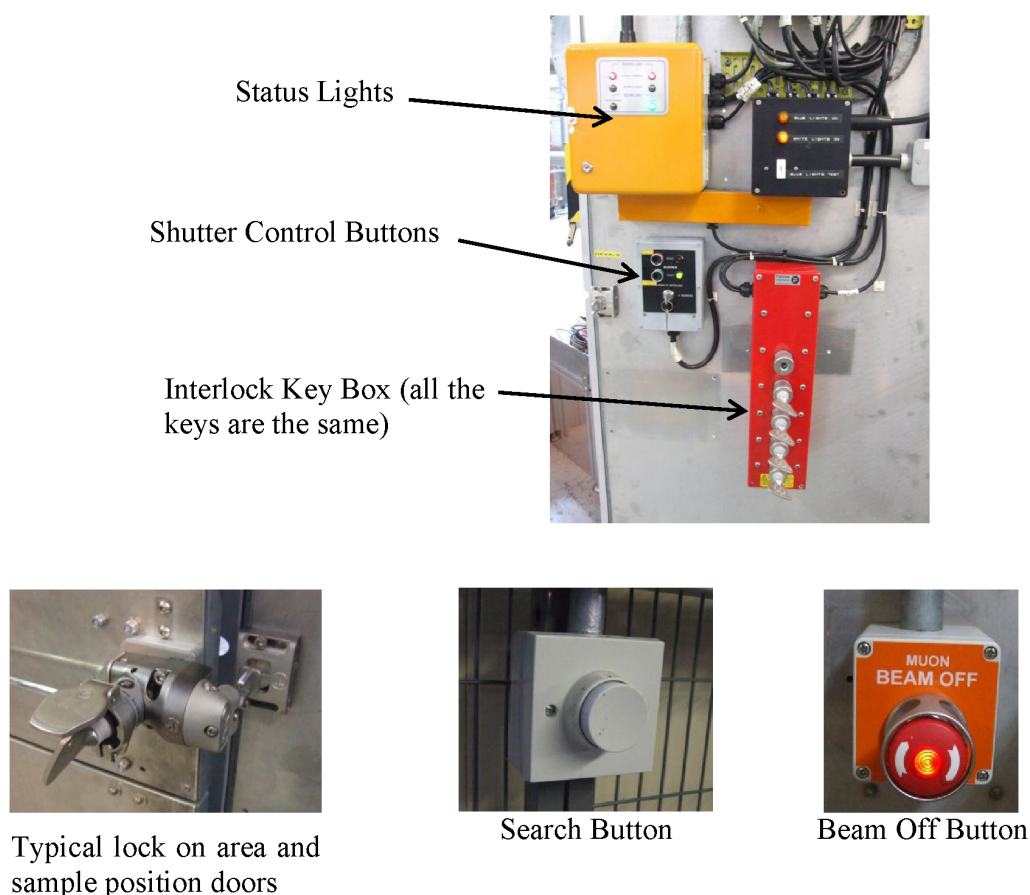


Figure 2: Interlocks in the EMU area

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 left behind in the area by accident when the blue lights come on should press one of the emergency “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 (type `f0` in SECI, or `r.f0()` in IBEX). Confirm that the “Magnet On” light is extinguished.
For basic SECI commands for running the instrument, see Sec. 6.1.3.
For basic IBEX commands for running the instrument, see Sec. 7.2.
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.

3 Sample Environment

The following sample environment equipment is available on EMU.

Table 1: Temperature ranges

Equipment	Temperature range [K]
Closed cycle refrigerator (Sec. 3.2)	8 – 800
Oxford Instruments Sorption Cryostat	350 mK – 50 K
Oxford Instruments Variox Cryostat	1.5 – 400
OI “White” Variox (OXF-11, 12, 13, 14) and Beast (OXF-7)	1.5 – 400
OI Heliox inserts (He ³ sorption refrigerator)	250 mK – 80 K †
OI Kelvinox inserts (dilution refrigerator)	60 mK – 4.2 K
ICE dilution refrigerator	80 mK – 4 K
OI Flow Cryostat (Sec. 3.5)	4 – 400
Dilution refrigerator	30 mK – 5 K (300 K)
Hotplate furnace	300 – 1000
Reflector Furnace	300 – 1500
Julabo oil bath A40	-40 – 250 C

† Note that the maximum temperature for Heliox and Kelvinox inserts can be extended to RT by putting a small amount of exchange gas in the cryostat. You will then need to change the SECI/IBEX configuration to the normal Variox mode.

Sections below describe how to use these SE kits. Those which do not have detailed description require your local contact to help for set up.

3.1 Adapters (instrument scientists only)

Some of the top-loading SE kits are shared between other instruments and may require a proper adapter to adjust their position in EMU. The adapters are sandwiched between the cryostats and top flange of the instrument cruciform. The following figures and table summarises which one should be used for each kit.

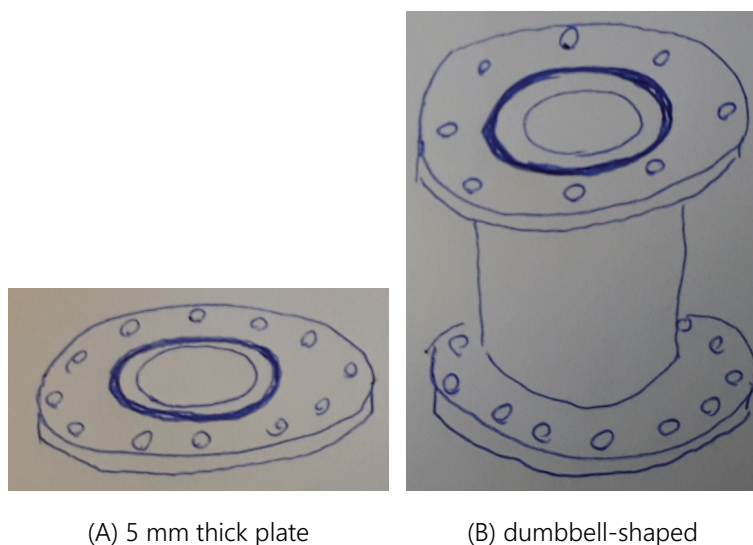


Figure 3: Adapters for top-loading SE kits To be replaced with decent photos.

Table 2: Adapters for top-loading SE kits

Equipment	Adapter (See Fig. 3)
OI Beast cryostat (OXF-7)	No adapter
HIFI-type OI “White” Variox cryostat (OXF-11, 12)	B
Beast-type OI “White” Variox cryostat (OXF-13, 14)	No adapter
ICE dilution refrigerator	A
OI Flow Cryostat	A

3.2 Closed-cycle refrigerator (CCR)

3.2.1 Thermometer selection

The CCR operates from 8 – 800 K, however two thermometer ranges (RhFe and Pt) are required to cover this region accurately. Ask your local contact to switch the sample thermometer between the RhFe (for $T < 320$ K) and Pt thermometers as required. The CCR head has a fixed Pt thermometer, which is read by Eurotherm #1.



Figure 4: Eurotherm 1 and 2

- 8 – 320 K ... configuration: **CCR_RhFe.conf** (SECI), **CCR_RhFe** (IBEX)
This only uses the RhFe (30 point calibrated thermometer). The heater should be plugged into Eurotherm #2 (see Fig. 4). 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.
- 20 – 320 K ... configuration: **CCR.conf** (SECI), **CCR_RhFe_pt100control** (IBEX)
This uses the Pt on the CCR head as the control thermometer and the RhFe as the sample. The heater therefore should be plugged into Eurotherm #1. This is safe as the control thermometer is always attached to the CCR. It can 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).
- 30 – 550 K ... configuration: **CCR_highT.conf** (SECI), **CCR_highT** (IBEX)
Two Pt thermometers are required. Heater should be plugged into Eurotherm #1. Optionally, the booster heater can also be used, and should be plugged into Eurotherm #2.

3.2.2 Loading a sample and cooling the CCR

1. Make sure all parts of the CCR are perfectly dry, using the hair dryers if necessary.
2. Screw the sample blade (see Fig. 7) onto the end of the CCR, using the small brass screws provided.
3. Ensure the correct thermocouple has been selected and that this is secured to the back of the sample blade with a small screw. During this procedure make sure you **DO NOT BEND THE THERMOMETER LEADS**.
4. Choose a proper sense current for the selected thermometer with a toggle switch in front of Eurotherm #2. Plug a heater cable into the Eurotherm unit and switch it on.
5. Replace tail sections (push fit). Take particular care when replacing the end section, ensure firstly that the windows are aligned correctly and secondly no part touches the sample.
6. 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.

7. Close the cruciform vent valve (see Fig. 5).
8. Fully open the large gate valve by winding the handle. If it is too tight, check if the direction you are winding is correct.

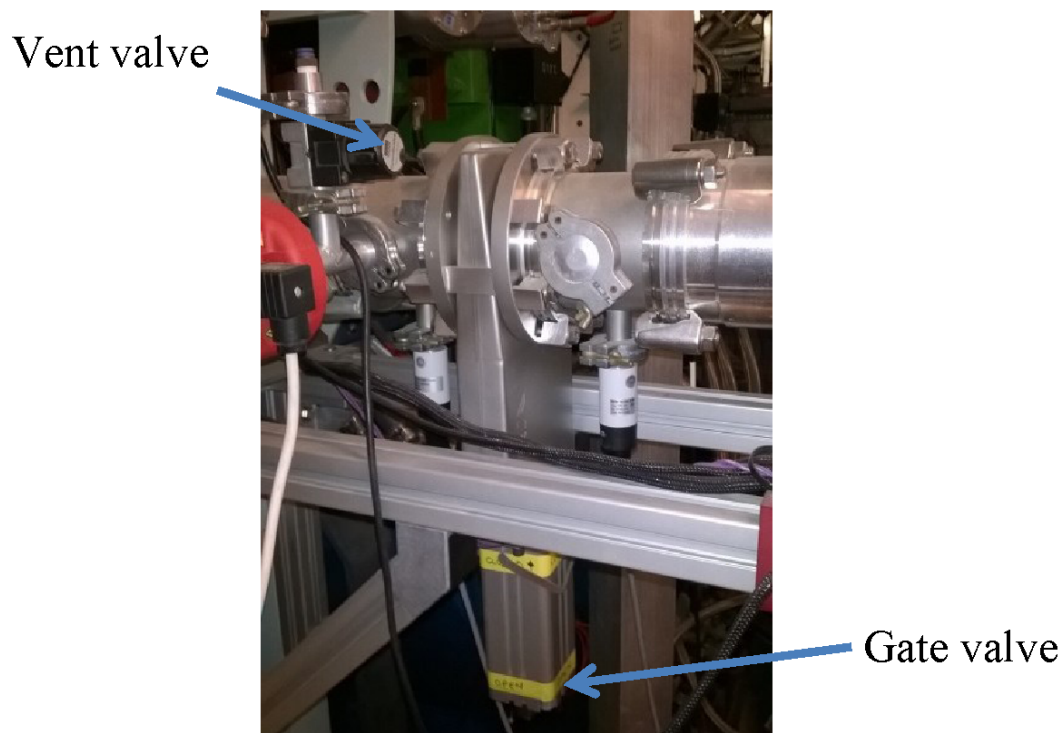


Figure 5: Vent valve and Gate valve

9. Start the vacuum pump (using the right-hand button on the TCP350 panel. See Fig. 6). 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 (~20 minutes).
10. The cruciform pressure is displayed by the digital readout adjacent to the pumping unit controls.
11. Below 10^{-3} torr the CCR compressor may be switched on by pushing the ON button on the compressor box, which then starts cooling the CCR head.
12. Cooling from room temperature (whole CCR warm) to base should take about 120 minutes. If the compressor has been running a while and sample temperature held at 300 K, subsequent cooling should take only one hour. During your experiment the compressor should be running at all times.

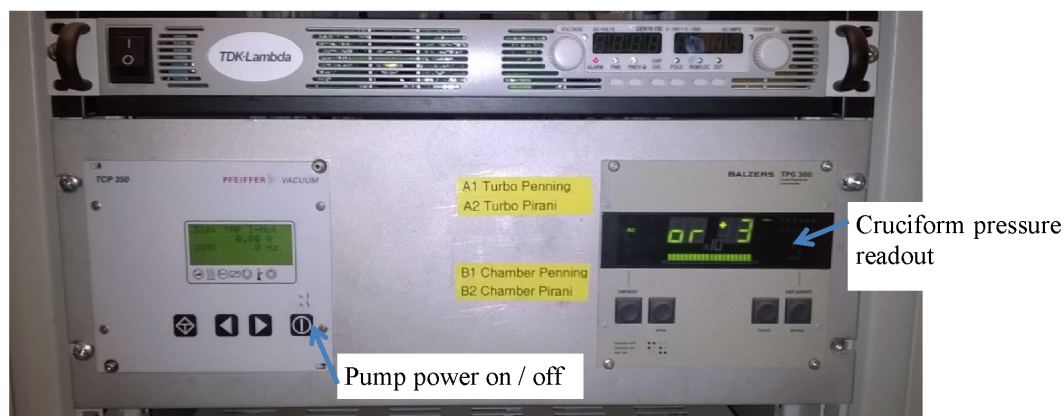


Figure 6: Vacuum pump and pressure readout

3.2.3 Changing the sample

1. Set the temperature to 300 K.
2. Turn the compressor off.
3. Close the large isolation valve on the side of the cruciform.
4. Switch off the pump using the right-hand button on the TCP350 panel.

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

5. Open the upper vent valve to vent the cruciform.
6. Slide back the CCR unit.
7. Switch off the heater using the toggle switch on the Eurotherm unit.
8. Remove the heat shield. You may need to use heat insulating gloves as the tail sections are still cold. Change sample.

3.2.4 Sample holder

A sample holder drawn in Fig. 7 shows its typical dimensions and is looking along the beam direction. There are a few versions, including fly-past holders. The holder is made of aluminium, titanium, or silver (fly-past holders), so therefore non-magnetic. Ask your local contact for the best way of mounting your sample.

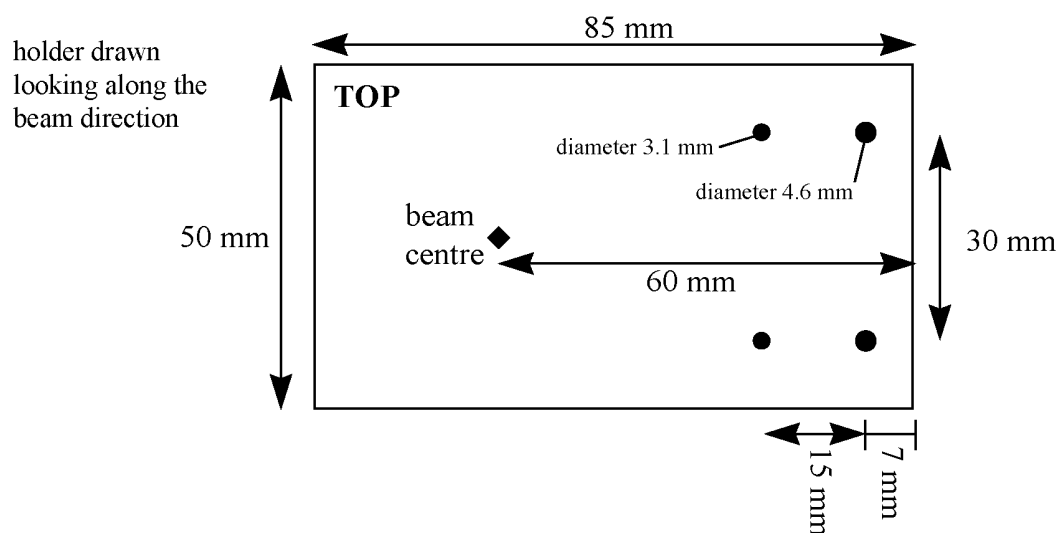


Figure 7: Sample holder for CCR

3.2.5 Booster heater

In the high-temperature configuration, the booster heater can be used to bring the sample plate up to the correct temperature. The booster heater consists of two cartridge heaters on a copper mount, which is screwed onto the booster heater sample plate (which has an extra hole near the centre for this purpose), as shown in Figure 8 (left).

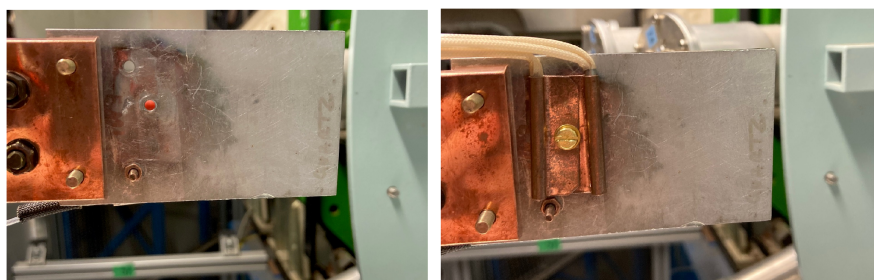


Figure 8: CCR booster sample plate, without (left) and with (right) the booster heater attached. Note that the thermometer is attached on the other side of the plate.

Using the booster heater requires the following steps (ensure that the CCR is warm and dry first by following the 'changing the sample' steps above):

1. Ensure the 'HTR' switch on Eurotherm #2 is off.
2. Remove the translucent yellow tape from the CCR cold head, and locate the red two-pin connector. Insert the booster heater into this.
3. If you have not already done so, attach the Pt sample thermometer to the correct lead on the cold head.
4. Mount the CCR booster heater sample plate, and attach the heater and thermometer as shown in Figure 8 (right).
5. Replace the tape on the CCR cold head.

6. Ensure that the black wire labelled HTR2 is plugged into the HTR connector on the top black junction box (located below the CCR), and the other end is plugged into Eurotherm #2.

Operating the CCR with the booster heater is largely the same as with the cryostats: use the command `r.boost()` before setting the temperature to use the booster heater, and `r.noboost()` to not use the heater. When heating, the sample and CCR temperature will overshoot the desired temperature slightly (by about 1 K), before coming down to the set temperature in a few minutes. When cooling, the code will switch both the CCR and booster heaters off until the sample plate is around 10 K cooler than the desired temperature, and after that it will switch the heaters back on to reach the set temperature. **Never change the maximum output of the booster heater, as this can damage the hot stage of the CCR.**

3.3 Sorption cryostat ... this section is obsolete

configuration required: **he3.conf**

The sorption cryostat 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.

3.3.1 Sample mounting

1. Load sample onto a sample plate (see below).
2. Mount the plate onto the sample blade, using the usual precautions for low temperatures and cold finger cryostat.
3. Clean and re-grease both sides of the cone seal, then pump and rotate the sample can by 180 degrees (this is done by the cryogenics team).
4. Install the cryostat on the EMU cruciform and start pumping for cooling.

3.3.2 Computer control

1. Load the .conf file to change the configuration to the He3 Sorption Cryostat.
2. Ensure the LabVIEW VIs in both tabs (Muon Temp Panel and He3) are running.

3.3.3 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 valve $\sim 10 - 12$ %. Note: the motor for NV has been removed. you have to open/close the valve manually.
3. Leave for 30 minutes with the 1 K Pot temperature less than 1.7 K and the Sorp at 40 K.
4. Open the needle valve to ~ 25 %, and cool the Sorp to 4 K, but remember to close the needle valve 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.

3.3.4 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.

3.3.5 Sample holder

Sample holders designed for the MuSR dilution fridge or the EMU Variox cryostat can be used in the sorption cryostat (the 40 × 40 mm plate); 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.

3.4 Helium cryostats:

“White” Variox (OXF-11, 12, 13, 14) and Beast (OXF-7)

The OXF-7 (Beast) cryostat should be used in combination with the ITC and ILM unit for controlling temperature and monitoring cryogen levels. The other helium cryostats, OXF-11, 12, 13, and 14, are connected to a single Mercury controller configured either in the needle valve or pressure control mode; the selection depends on whether each cryostat is equipped with a pressure transducer on helium extraction. But since we don’t have a script for the pressure control yet (*i.e.* helium flow need be controlled manually), use the NV control for a standard use of helium cryostats. The pressure mode is particularly useful when used with a Heliox or Kelvinox insert, where the cyrostat tempearture is basically set at the base.

Table 3: Configurations for helium cryostats

Equipment	SECI	IBEX
OXF-7	Beast_itc502.conf/Beast_itc503.conf	Beast_ITC502/Beast_ITC503
OXF-11~14 NV	White2_Merc2.conf	OXF11

Note that 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.

3.4.1 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 endeavor 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.

Beast OXF07: No spacer is necessary. The cryostat should be set up directly on the cruciform. **White OXF11, OXF12:** An adapter is required. (the 5 mm spacer is NOT necessary.)

3.4.2 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

3.4.3 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).

3.4.4 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.**

3.4.5 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. First, `settemp` to 10 K and wait for the cryostat temperature is stable. 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”. The temperature should drop rapidly. Small adjustments to the needle valve may be needed to ensure a stable temperature (from the vi window on SECI, or from the device screens if the instrument is running on IBEX). Ensure that the temperature can be stabilized at the desired base temperature. 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.

3.4.6 Sample holder

The sample holder is a 40 × 40 mm square plate, which 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 (see Fig. 9 for Beast). A small amount of grease should be placed between the sample plate and the blade to ensure good thermal contact. A silver mask may be used as appropriate to reduce the background.

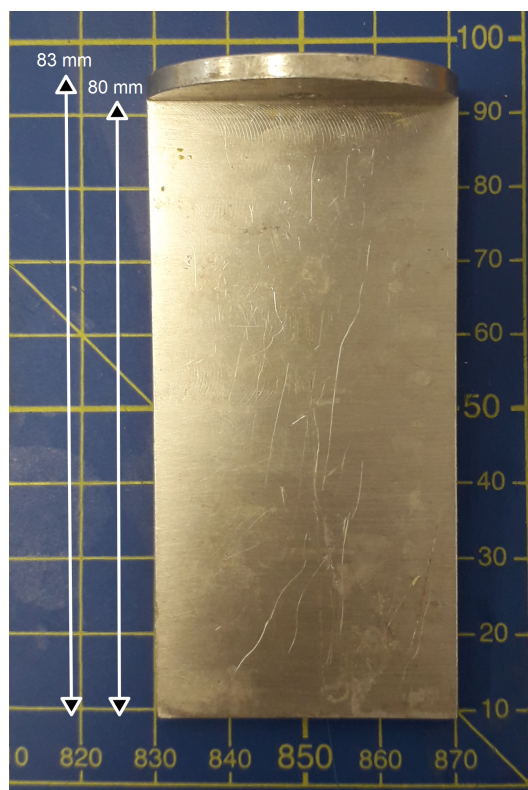


Figure 9: Sample blade for Beast cryostat

3.5 Small flow cryostats

SECI Configuration Names: Flow_itc502.conf, Flow_itc503.conf

Fig. 10 and Fig. 11 illustrates the small flow cryostat and its sample stick respectively. The temperature range is 4 to 400 K for the normal flow cryostat and 6 K – 600 K for the cryofurnace flow cryostat. **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. Use the appropriate ITC5 temperature controller for the cryostat. Start pumping the OVC using a turbo pump.

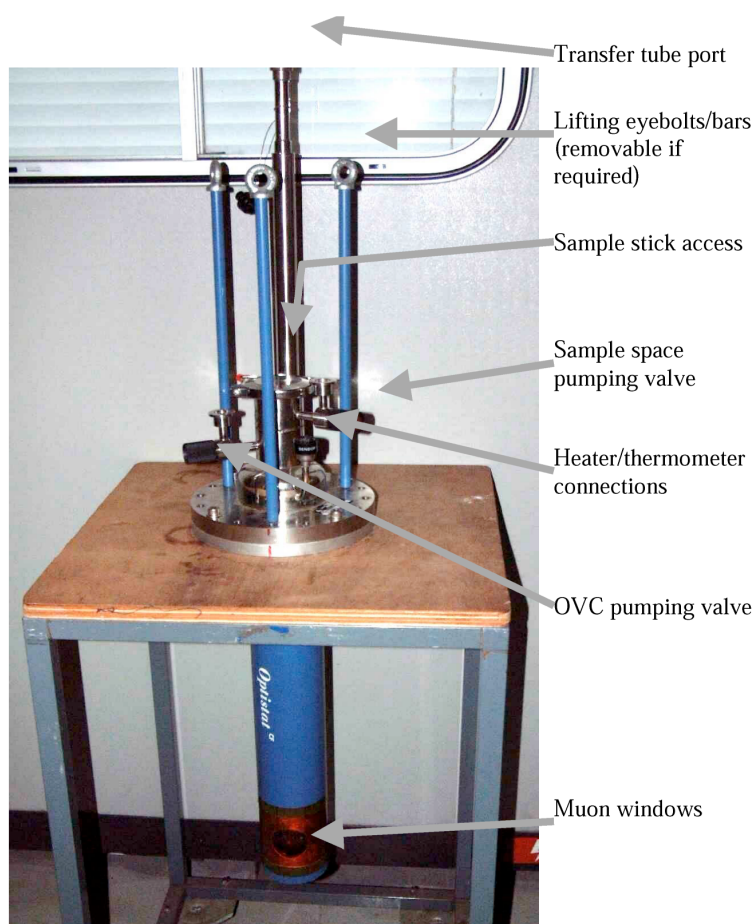


Figure 10: Overviewing the small flow cryostat

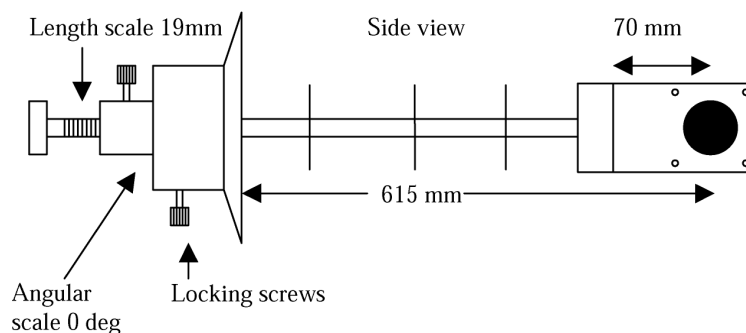


Figure 11: Schematic of sample stick for the small flow cryostat

3.5.1 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.

3.5.2 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.

3.5.3 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 and 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.

3.5.4 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 valve and switch off and disconnect the turbo pump.
6. Remove the cryostat.

3.5.5 Sample holder

The flow cryostats use the same sample holder as those used with the Oxford Instruments Variox. See Sec. 3.4.6.

3.6 Dilution Refrigerators

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

3.6.1 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.

3.6.2 The ICE Fridge

This fridge is currently under development. **A 5 mm spacer plate must be screwed onto the top port of the EMU cruciform before this cryostat is mounted.**

3.7 Hotplate Furnace

SECI Configurations: Hotplate_furnace.conf

The muon furnace is designed to allow μ SR 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 μ m) 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 μ m 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:

<https://www.isis.stfc.ac.uk/Pages/muon-hotplate-and-optical-furnace-operation.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. **All set points and recorded temperatures are in C NOT K.**

3.7.1 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.

3.8 The Reflector Furnace

SECI Configurations: Reflector_furnace_highT.conf, Reflector_furnace_lowT.conf

For further details, please refer to the furnace manual:

<https://www.isis.stfc.ac.uk/Pages/muon-hotplate-and-optical-furnace-operation.pdf>

3.8.1 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.

4 Magnetic Fields

4.1 Longitudinal magnetic fields

Longitudinal magnetic fields up to 4500 G are provided using Helmholtz coils, powered by the large Danfysik power supply (Model 859, 210 kW). Fields of up to 5000 G can be used after discussion with your local contact. The supply is controlled from SECI/IBEX, and in normal operation no manual intervention at the supply is required. The SECI command `lf0` selects this magnet power supply and subsequent `setmag` commands will adjust the field strength.

4.1.1 Danfysik 9100 for a better field accuracy

A smaller Danfysik power supply (Model 9100, 7 kW) is also available for the longitudinal field, which allows you to set fields up to 260 G with a higher accuracy. For using this PS, your local contact will need to change the configuration at the supply.

- *Instrument scientists ONLY:*

1. To change from Danfysik 859 to 9100, firstly issue the `f0` command and ramp the field down to zero
2. At the supply (says “DANFYSIK SERIES 859 210KW PSU 210KW PSU (100VDC/2100A)”), turn the black switch from the “ON” to “OFF” position and remove the interlock key (“HI_PSU”) located just below
3. At the side panel (where you can find a turn switch with a long handle and 4 key sockets), return the key to its socket (these are labelled). Turn it clockwise (for about 60 deg) to the locked position. Key positions are labelled on the sockets (E for engaged and R for release)
4. Then remove a key from the C/OVER socket by turning it counterclockwise to the R position
5. Turn the long handle for 90 deg (clockwise) and change its position from POSITION 1 DANFYSIK SERIES 859 to the “OFF” position. Subsequently, turn it to the POSITION 2 DANFYSIK 9100 SERIES position. Note that this handle is heavy
6. Put the key in another C/OVER socket for Danfysik 9100 and turn it clockwise to the E position (*Note:* wiggle the handle if you find the turning is stiff)
7. Turn the LOWPSU key counterclockwise and remove it
8. Put it in its socket at the 9100 supply and turn it clockwise to the locked position
9. Turn the red turn switch positioned just above. This will start the supply controller

10. Turn the circuit breaker on
11. Now you should be able to talk to the supply from IBEX. The IBEX configuration is described elsewhere in this manual
12. After your experiment, please make sure to set it back to the 859 supply

4.2 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 subsequent `setmag` commands will adjust the field strength.

4.3 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 KEPCO supply located in the rear part of the EMU cabin. Increasing the current in a positive 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.

4.4 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.

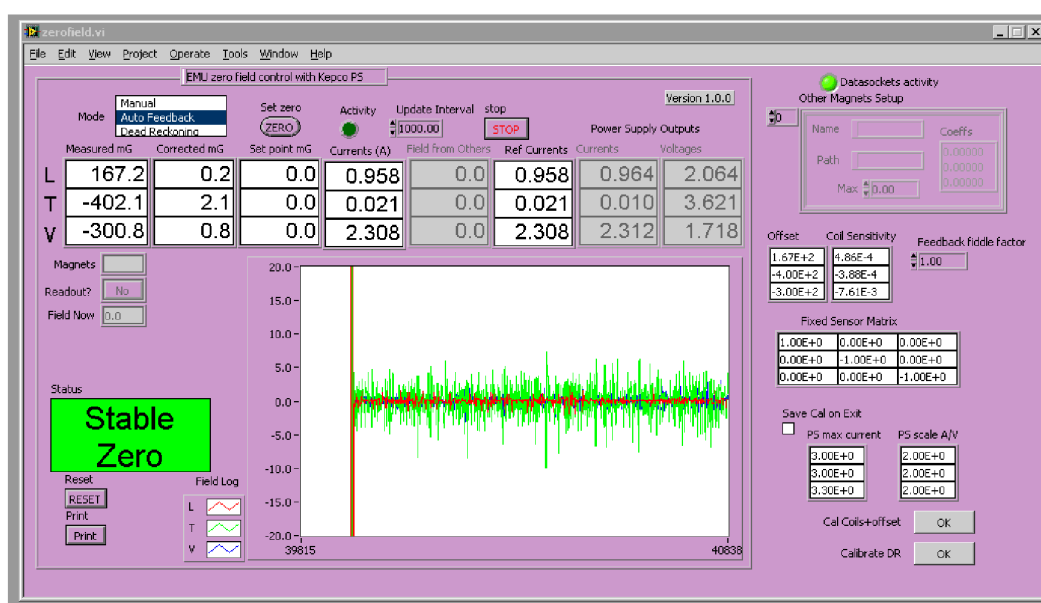


Figure 12: LabVIEW VI window for zero field compensation coils

5 Computing

5.1 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.

5.1.1 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 aremote 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 6.

5.2 Monitoring your experiment

If you are away from the experimental hall, the ISIS beam current and MCR messages are available at

<https://www.isis.stfc.ac.uk/Pages/beam-status.aspx>

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.

5.3 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:

<https://data.isis.stfc.ac.uk/>

(or ISIS Remote Data Access at <https://data.analysis.stfc.ac.uk/>)

You will need your STFC credentials for log in. 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.

5.4 Data analysis

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

5.4.1 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 4 μ^+ ” is available on the ISIS Muon web pages:

<https://www.mantidproject.org/images/archive/f/fa/20140709103517%21Mantid-4-muons12915.pdf>

5.4.2 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:

<https://www.isis.stfc.ac.uk/Pages/Muons-Downloads.aspx>

Loading run 0 will load the run currently in progress.

5.5 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>

5.6 Printers

A printer, “R55-MUSR”, is situated inside the hotdesk cabin, and this is available from any PC.

6 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.

6.1 Running SECI

6.1.1 Starting SECI

SECI must run from the EMU account on the NDXEMU workstation (see section 5.1.1 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.

6.1.2 Changing configurations

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

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

6.1.3 Common SECI commands

- Starting a Run: **begin**
- Ending a Run and saving the data: **end**
- Ending a run without saving: **abort**
- Pausing a run: **pause**
- Then to continue the run: **resume**
- Setting a temperature in K: **settemp *value***
- Setting a field in G: **setmag *value***
- Setting the slit position: **slits *value***
- Selecting power supply for transverse field and setting 20 Gauss: **tf20**
- Selecting Danfysik power supply: **lf0**
- Selecting auto-zero-field: **f0**
- Waiting for value seconds: **sleep *value***
- Setting the label: **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 orientationYou will be prompted for information.
- Displaying all control blocks: **cshow/all**

6.1.4 SECI commands for blue cryostat

- For operation below 5 K: **blue_lt**
- For operation above 5 K: **blue_ht**

6.1.5 Temperature parameter files

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

6.1.6 Stopping SECI

On NDXEMU, if SECI is not responding then under file option select exit or select KILLSECI on the start menu.

6.2 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.

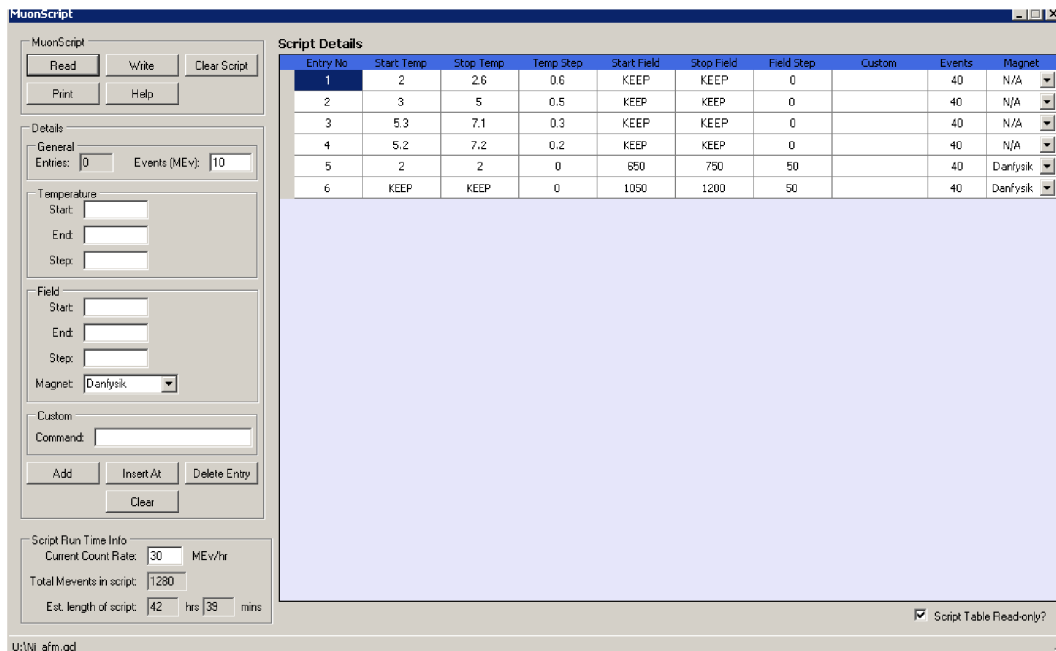


Figure 13: MuonScript window

- **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 run a script, in the OpenGENIE window

- Loading a script: `load “yourscriptname.gcl”`
- Running the loaded script: `runscript`
- Ending the script: `<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.

7 IBEX

From Cycle 2019/4, IBEX Instrument Control Software has been introduced on EMU, taking over the previous instrument software SECI. The new control system is based on the modern EPICS technologies and Python language. For details of IBEX visit their website

<https://www.isis.stfc.ac.uk/Pages/IBEX.aspx>

where a user manual can be downloaded. One can also find it in the IBEX window under the **Web Links** view. Their wiki website has recent updates on the IBEX development

<https://github.com/ISISComputingGroup/IBEX/wiki>

Similar to SECI, all commands should be entered into the Python console on the dashboard under the **Scripting** view. The original Open Genie commands have been translated into `genie_python`, which provides a library containing very similar commands used in SECI.

7.1 Running IBEX

Similar to SECI, IBEX must run from the EMU account on the NDXEMU computer (see section 5.1.1 for logging in). It is possible to run an experiment using only a small number of commands; these are all typed in the Python (PyDev) console. It is important to note that Python commands are **case sensitive**.

7.1.1 Changing configurations

Like SECI, IBEX also has configurations for each experimental setup used in EMU. Every time the sample environment is changed, the appropriate configurations must be opened.

1. Select **Configuration** from the menu bar.
2. Select **Load** from the drop-down list. You will find a list of available configurations on a separate window.
3. Choose one and click on **OK**. Wait for the loading to finish.

At the moment the following configurations are available:

Beast_ITC502, Beast_ITC503, CCR_highT, CCR_RhFe, CCR_RhFe_pt100control,
hotplate_furnace, ITC503_flow_cryostat, OXF11, reflector_furnace_lowT

The name convention basically follows from SECI, and we plan to migrate all of the SECI configurations in due course.

7.1.2 Temperature parameter files

Each time the `r.settemp()` command is issued, IBEX loads parameters from the `tpar` file. Therefore to adjust the temperature parameters (such as PID values), find the file in the following directory, open it with a text editor, change and save the file.

`C:\Instrument\settings\config\NDXEMU\configurations\tpar\`

Then the next time `r.settemp()` is issued, IBEX will use the new parameters.

Note: Please do NOT change files ending with `.tpar.bak` as they contain the original parameters.

7.1.3 Alarms

IBEX raises colour-coded alarms depending on the type of issues. Briefly they are:

- **Purple:** communication issues. IOC is disconnected from the system and cannot communicate.
- **Orange:** something minor. It can be *e.g.* that a parameter read-back is out of the range.
- **Red:** Major issue. IOC communicating but the parameter is in the wrong range.

7.1.4 Stop/restart the Python console

Sometimes you may need to restart the Python console. Clicking on the red button in the upper right corner of the console window immediately removes the console. Start a new console by selecting `PyDev Console` → `Python Console` → `OK`.

7.2 Common IBEX commands

Common Open-Genie commands in SECI have been migrated to IBEX under the name space `r`. Therefore when entering a command in the Python console, type, for example,

```
>>> r.begin()
```

to start a run. **Do not forget the brackets even if you have no parameters.** If any parameters, they are placed inside the brackets.

Below shows all the μ SR commands in IBEX available to date.

- `r.begin()` starts a run. By default, `quiet=False` so it'll ask you for run information.
- `r.end()` ends and saves a run. By default, `quiet=False`.
- `r.abort()` aborts a run.
- `r.pause()` pauses a run.
- `r.resume()` resumes a paused run.
- `r.load_script("filename.py")` loads a script "filename.py".
- `runscript()` starts the script (you don't need "r." for this).
- `r.settemp(temp, wait=False)` sets temperature `temp` normally in K. `wait` (bool) whether to wait for the temperature to stabilize before returning. Defaults to `wait=False`. The wait time is defined in the `tpar` file.
- `r.setmag(field, wait=False)` sets a `field` (in Gauss) in the currently selected magnet. `wait` (bool) whether to wait for the field to stabilize before returning.
- `r.slits(gap)` sets the slits to `gap` (in mm).
- `r.tf0()` zeros the instrument's magnetic field, and switch to using the transverse field coils.
- `r.tf20()` sets a field of 20 Gauss in the transverse coil.
- `r.lf0()` zeros the instrument's magnetic field, and switch to using the longitudinal field coils.
- `r.f0()` zeros the instrument's magnetic field, and switch to using the zero-field compensating system.
- `r.sleep(sec)` pauses the process for `sec` seconds.
- `r.blue_lt()` changes the needle valve to manual for temperatures < 4 K, and sets the temperature to 1 K.
- `r.blue_ht()` changes the needle valve to auto for temperatures ≥ 4 K.
- `r.boost()` enables a booster heater for quick heating. The command also reads a PV value and changes the `Cryostat_Booster` block to the correct type. At EMU, the boost mode is available on cryostat sticks and CCR.
- `r.noboost()` disables a booster heater on the sample stick, and turn off the booster heater.
- `r.disable_auto_onoff()` disables auto onoff function on the Danfysik power supply. This function is supposed to be used with ULT kits and avoid unwanted heating due to the Eddy current.
- `r.enable_auto_onoff()` enables auto onoff function on the Danfysik power supply.

- `r.setlabel()` sets labels. Available arguments are (all in string):
 - `sample_name`: name of the sample
 - `orientation`: orientation (including *e.g.* “plate” or “powder”)
 - `temperature`: sample temperature
 - `field`: applied field
 - `geometry`: beamline geometry *e.g.* “1”
 - `rb_num`: RB number for this experiment (only the number)
 - `exp_team`: Experimental team
 - `comment`: An arbitrary comment

Examples:

To change the sample name and comment:

```
>>> r.setlabel(sample_name="MySample", comment="my comment for this sample")
```

To get detailed help on a particular command, use the help command. For example, for help on `r.settemp()`,

```
>>> help(r.settemp)
```


7.3 Script writing

ScriptGenerator replaces **MkScript**, and helps to write an instrument script in Python. Generated scripts can run on the Python console under the **Scripting** view (do not use the **Script Server** view at present). Click on an icon of a circle with three horizontal lines on the Windows taskbar. Note that the UI windows are represented by an icon of a hammer.

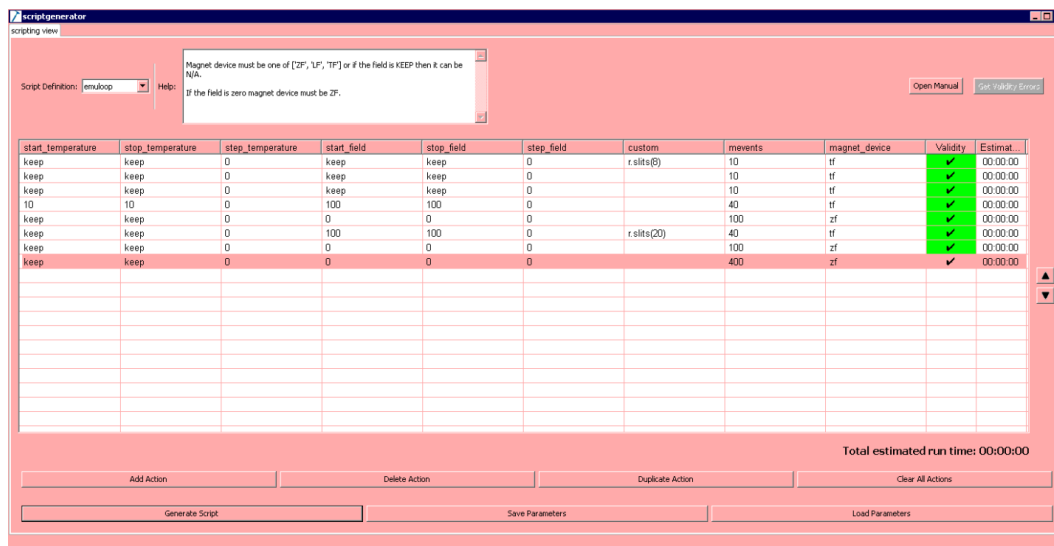


Figure 14: ScriptGenerator window

First choose **emuloop** from the **Script Definition** pull-down menu. Add an entry by clicking on **Add Action**. You can duplicate a highlighted entry by clicking on **Duplicate Action**. Click on the cells to enter the temperature and/or field values. You can use the **tab** key and **shift + tab** to move the cursor around. When **keep** (case insensitive) is entered, the script uses the existing temperature/field and do nothing. If the start and stop temperature/field are the same, **step** should be 0. If you scan both temperature and field in the same entry, **IBEX** will scan the field first for each temperature. If a command is entered in the **custom** cell, the custom command runs first. If any problems are found in an entry, the **Validity** cell returns errors (shows a “×”, otherwise “✓”). When you finish the script table, click on **Generate Script**. It automatically saves the script in **C:\scripts**, with a filename using the system time stamp. Clicking on **Open file** will open the generated script with **Notepad++**. Right-click on the tab and select **Filename to clipboard** to copy the file name. Then go to the Python console and type

- `r.load_script("filename.py")` to load the script. Then
- `runscript()` to start the script.

You can interrupt the script by **<ctrl> + c**. Any run currently under progress will continue, and can be ended in the normal way by typing `r.end()` into the console.

7.3.1 Reloading a script

With **ScriptGenerator**, you cannot reload a generated **.py** script directly back into the software. However, when a script is generated, a **.json** file is also created, which contains all the experimental parameters in the script. This file can then be used to reload the same set of measurements on the UI.

7.4 Asking for support/Submit a bug or problem

Go to **Web Links** → **Submit a bug or problem**. A separate window will open for the report form. For urgent problems contact your local contact first, then call for support.

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 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. The detectors are numbered as follows:

Forward detector bank:

Inner 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.

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

Backward detector bank:

Inner 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.

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

Looking in the instrument from the downstream of the beamline, detectors are numbered clockwise from the triplet at 12 o'clock (detectors 1-2-3 in the forward bank and 49-50-51 in the backward bank). There are triplets at 3, 6, and 9 o'clock, with three triplets in between, forming a total of 16 triplets in the forward and backward detector banks.

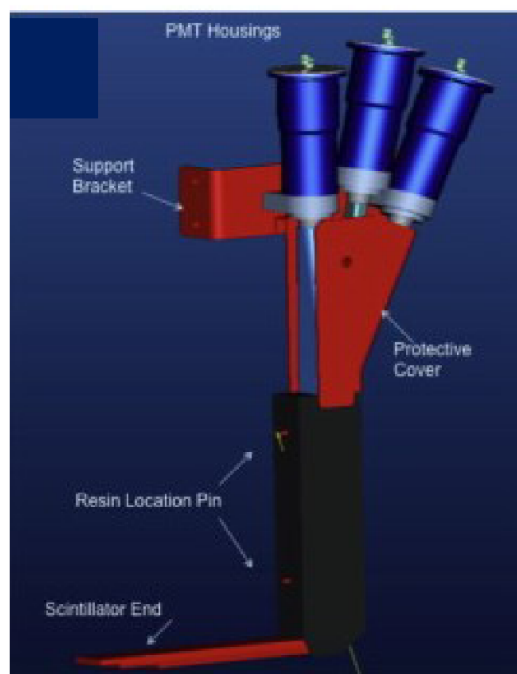


Figure 15: Detectors are constructed in groups of three.

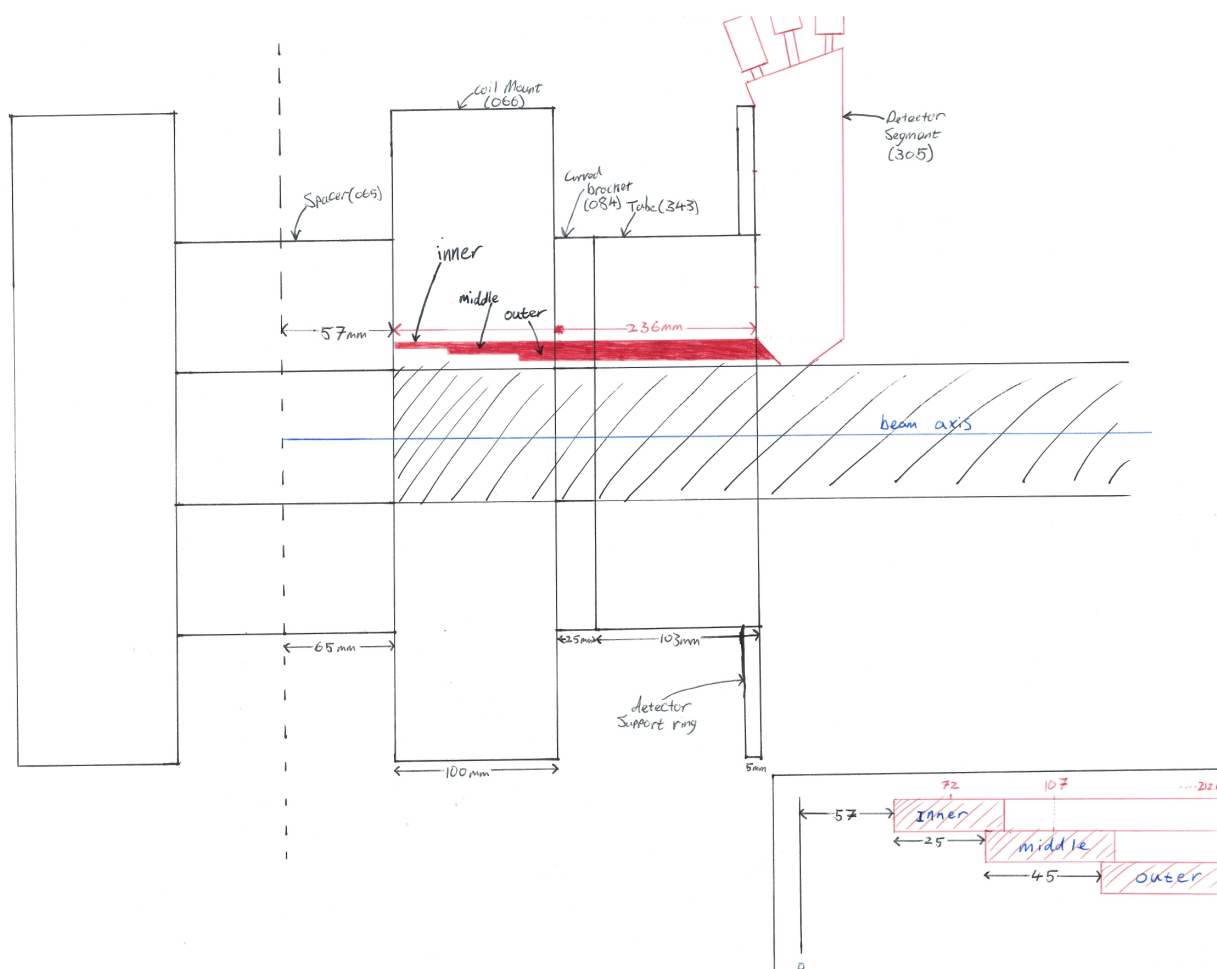


Figure 16: Side view of the instrument and triplet

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 $\sim 25 \times 10 \text{ mm}^2$ 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 [mm]	4	8	12	16	20	30
Fraction 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 [mm]	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” (FoM) of an instrument is given by $FoM = (\text{muon asymmetry})^2 \times R$, where the average event rate $R \equiv (\text{muon events counted}/\text{muons implanted})$.

8.3 Range curves

The muons in the beam hit the front surface of the sample at about $0.25 \times c$ 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 ($25 \mu\text{m}$, $12.2 \text{ mg}/\text{cm}^2$) 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.

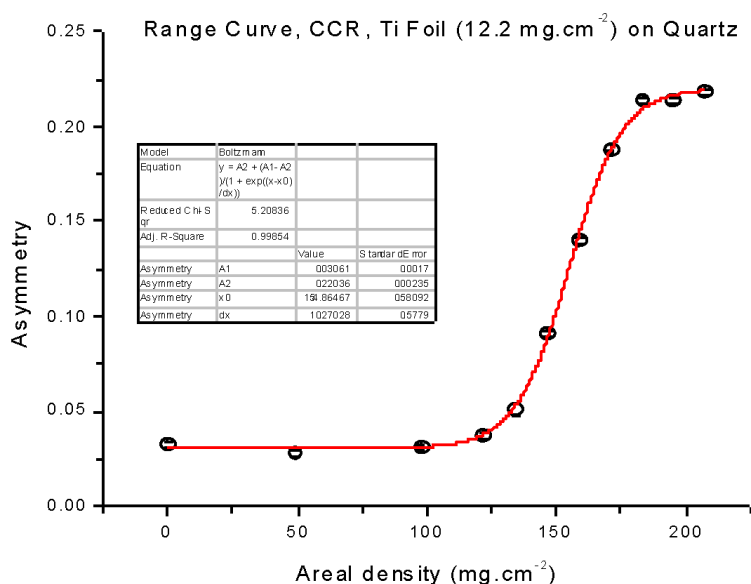


Figure 17: Range curve

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 70 ns FWHM) 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 shown in Fig. 18 shows the frequency response measured in September 2018, after the pulse compression in the ISIS Synchrotron.

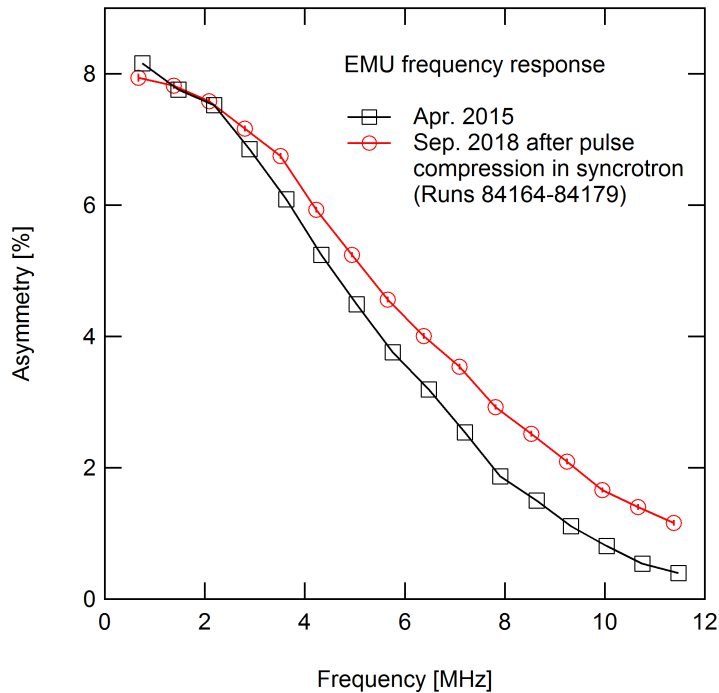


Figure 18: Frequency response

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 degrees 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 Fig. 19). Grouping the detectors, however, the effect is removed (as shown in Fig. 20) by the subtraction of the backward histograms from the forward set and analysis can proceed as normal.

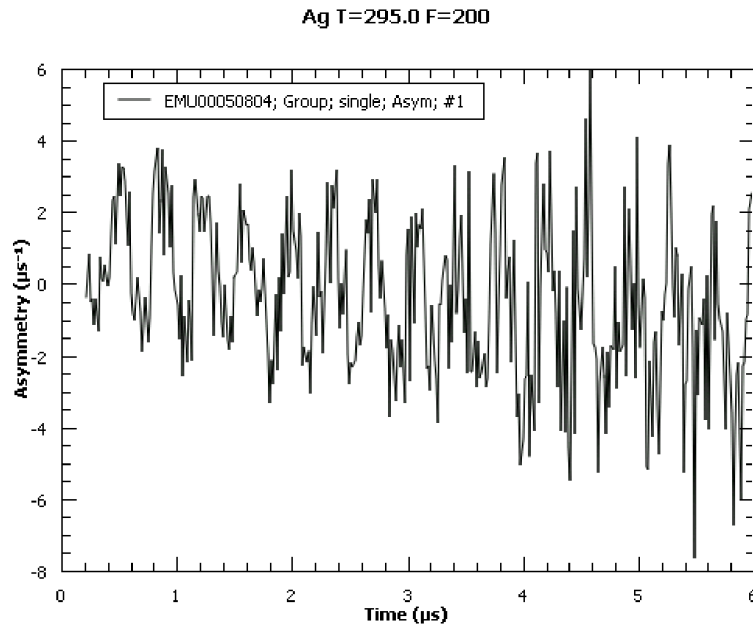


Figure 19: Precession of the muon spin

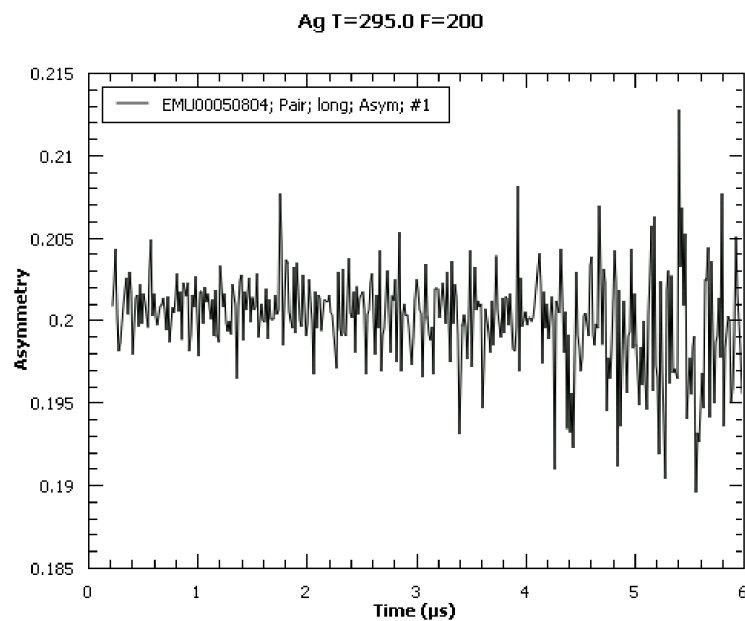


Figure 20: After grouping the detectors

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 1.5 asymmetry % 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 PMT tubes. The data presented in Fig. 21 was measured using an experimental set-up with a value of α close to one in low transverse 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.

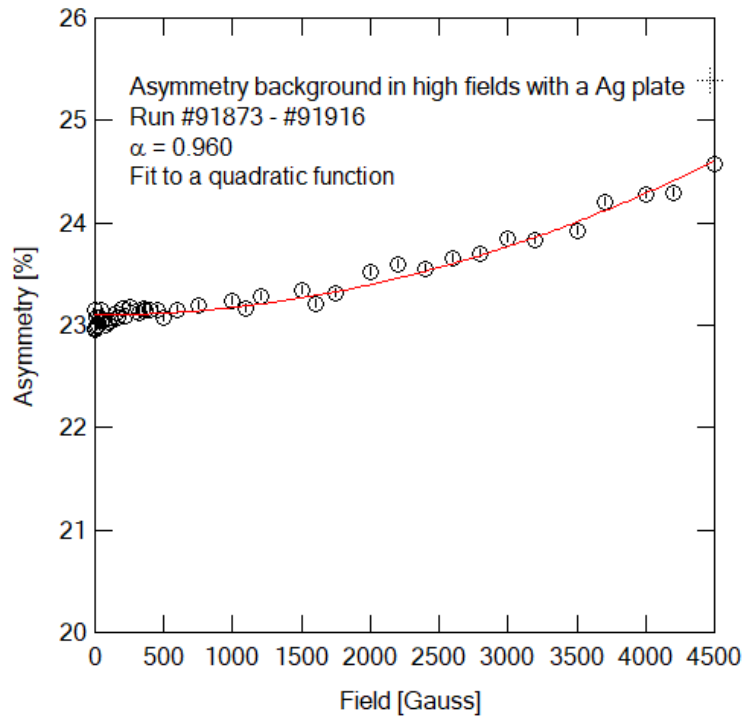


Figure 21: Change in muon asymmetry as a function of fields

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 $0.008 \mu s^{-1}$.
- **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. [The supporting data to be added here in due course.](#)

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 $5 \mu A$, the machine is probably at base rate (i.e. $1/32 \times 50$ Hz) and the updates of the histograms collected by the computer will be correspondingly slower.
- 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.
- When the IBEX dashboard says “DAE is waiting” and there is no counting, IBEX is on hold by its run control mechanism, which is triggered by one of the blocks. Have a look at blocks on the dashboard (hidden ones as well. Right-click on the dashboard and choose “show hidden blocks”) and look for a block(s) showing a red cross next to it. The run control could be on the vertical steering magnet. See Appendix B.2.

- 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.
- 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 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.
- 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.
- Check that the PMT 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.

9.2 Computer

If SECI crashes go to the start menu on NDXEMU and click on the KILLSECI.cmd. Once SECI has closed wait for 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:

1. Ramp down and deselect the magnets by typing `f0`.
2. Then try restarting the magnets by issuing the commands `tf20` or `lf0`.
3. 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 address and contact list

ISIS Neutron & Muon Source
 STFC Rutherford Appleton Laboratory
 Harwell Oxford,
 Didcot,
 Oxfordshire,
 OX11 0QX, UK

Main control room (MCR) & 6789 (+44 (0)1235 446789 from mobile or outside the lab)	
Site Emergency & 2222 (+44 (0)1235 778888 from mobile or outside the lab)	
RAL Security & 5545 (+44 (0)1235 445545 from mobile or outside the lab)	
User Office & 5592 (+44 (0)1235 445592 from mobile or outside the lab)	
EMU cabin	6831
MuSR cabin	6135
HiFi cabin	6851
ARGUS/CHRONUS cabin	6766
Health Physics (sample checking)	6696
Ridgeway House	5500
Cosener's House	3007
Taxi	5592 (during the night)

From outside the laboratory certain extensions may be direct dialled, the number being formed in the following manner: (01235) 44xxxx, 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:
<https://www.isis.stfc.ac.uk/Pages/Muons-People.aspx>

10.2 Site map

<https://staff.stfc.ac.uk/about/maps/Documents/RALSitePlan.pdf>

10.3 Other practical information for users

The User Office website gives very useful guide for facility users:
<https://www.isis.stfc.ac.uk/Pages/User-Office.aspx>

A Basic OpenGENIE script commands

A basic OpenGENIE script has the following structure. Variables are defined with the command LOCAL.

```
PROCEDURE RUNSCRIPT
LOCAL myTemp myField;
...
ENDPROCEDURE
```

- For setting the label:

```
setlabel/s sample= "value" for sample
setlabel/c com = "value" for comment
setlabel/u team= "value" for user
setlabel/rb rbno= value for RB number
setlabel/t temp = value for temperature
setlabel/f field = value for field
setlabel/g geo= value for geometry
setlabel/o orient= value for orientation
```

- For setting the field and temperature:

```
myfield = 100
SETLABEL/F FIELD=myfield
SETMAG/WAIT FIELD=myfield
```

```
myTemp = 290
SETLABEL/T TEMP=myTemp
SETTEMP/WAIT TEMP=myTemp
```

- To start and end a run without system reports:

```
begin/quiet
waitfor events=5
end/quiet
```

frames for good frames and seconds for real time are also available.

- To pause the script:

```
sleep value in seconds
```
- For a loop,

```
LOOP m FROM 1 TO Mmax STEP 1
...
ENDLOOP
```

B Hints for instrument scientists – IBEX

B.1 Switching between SECI/IBEX

During the transition period both IBEX and SECI are available on the NDXEMU machine in the case IBEX has any trouble.

- To switch from IBEX to SECI
 1. If you are running the IBEX Client, exit before stopping IBEX Server. Select `Exit IBEX Client` from the IBEX menu.
 2. Open a command window.
(alternatively, you can launch the `stop_ibex_server` script from a shortcut under the Windows Start menu)
 3. At the command prompt type the following:


```
cd c:\Instrument\Apps\EPICS
stop_ibex_server
```
 4. Allow the `stop_ibex_server` script a few minutes to complete. **You have to stop the IBEX server before launching SECI.** Running both will have unpredictable results!
 5. Start SECI from:


```
C:\Program Files (x86)\STFC ISIS Facility\SECI\SeciUserInterface.exe
```

 Alternatively, use a shortcut under the Windows Start menu.

Note: Because IBEX runs the server on the NDX machine, you can install an IBEX Client on your own computer and monitor your experiment remotely within the ISIS network. For details see the IBEX manual.

- To switch from SECI to IBEX
 1. Stop SECI by clicking on the `Kill SECI` icon in the Windows Start menu.
 2. Open a command window.
Alternatively, use a shortcut under the Windows Start menu.
 3. At the command prompt type the following:


```
cd c:\Instrument\Apps\EPICS
start_ibex_server
```
 4. Allow the `start_ibex_server` script a few minutes to complete.
 5. Start the IBEX Client from the taskbar icon.

B.2 Miscellaneous

IOC not working property In the case an IOC not working properly, first see if you can resolve the problem from the `Device Screens` view. If an IOC needs to be restarted, go to `Start/Stop IOCs` under `IOC` in the menu bar.

Setting an IOC in simulation mode This is an example for the Danfysik power supply. From the menu bar on IBEX Client, `Configuration` → `Components` → `Edit` → `Danfysik_highfield`. For the IOC `DFKPS.1`, change `Sim level` from `None` to `Recsim`. The IOC is now in the simulation mode. For changing it back to the normal state, choose `None`.

Simulated DAE (copied from github) The DAE can be placed into a simulation mode if you want to do an off-line experiment or test something out when the physical DAE is not usable. In simulation mode the DAE will count frames as normal and has a spectrum count in some spectra but it is not realistic. To turn this on/switch it off use in `genie_python`:

```
g.set_dae_simulation_mode(True)
g.set_dae_simulation_mode(False)
```

In simulation mode the dashboard should be coloured correctly and **SIMULATION MODE** is shown in large black letters.

No need to reload current configuration and this is discouraged in IBEX (you may notice that there is no current configuration in the **Load** window). One of the fundamental concepts of IBEX is to control each component independently so that a broken component does not affect the whole system. If you still need to reload the configuration, use the command `g.reload_current_config()` from the Python console.

Configurations and Components IBEX also has components, which are sublevel to the configurations and define controls on each experimental component, such as `EMU_base`, `beamlog`, and `Danfysik_highfield`. Handling these components in IBEX became significantly simpler than SECI.

Danfysik_highfield and Danfysik_lowfield EMU is normally set up with the Danfysik 859 PSU, which allows the instrument LF up to 4500 G (“high-field mode”). However you can switch to the Danfysik 9100 PSU, which gives a much better field resolution but a lower maximum LF up to 260 G (“low-field mode”). If you plan to use the low-field mode for your experiment, simply remove the `Danfysik_highfield` component from the configuration and replace with `Danfysik_lowfield`. **Please remember to switch this back** at the end of your experiment.

Zerofield compensation setup The IBEX team has developed scripts that measure fields (from the field probes) as a function of current on the compensation coils. These scripts can be useful to measure and calibrate the field response (mG/A) for the ZF compensation system. You can find them in

```
C:\Instrument\scripts\technique\muon\zero_field_setup.py
```

To run the setup commands, type in

```
zero_field_setup.run_zero_field_set_up()
```

Visible blocks To configure visible blocks, open the **Edit Component** window from **Configuration** on the menu bar (the **Protected** tickbox unchecked so you can save the change). Select which blocks to be visible by ticking/unticking the **Visible** blocks.

Finding the right PV for blocks Another tip with the blocks, if you are struggling to find the PVs you want to hook them up to, is to right click on the number you are interested in in the OPI and press “**Show PV info**”.

Manager mode You can protect configurations and components in the manager mode. To enable the manager mode go to IBEX → **Manager mode** on the menu bar. Then you can enable and save the **Protected** tickbox on the configuration/component windows. When finished log off the manager mode.

Configure the temperature graph When a Python console is started, it automatically loads a code to display a temperature plot next to the console. If you need to modify the graph go to

```
C:\Instrument\settings\config\NDXEMU\Python\init_emu.py
```

and edit the following line to add or rename blocks on the plot:

```
background_plot=BackgroundBlockPlot(("Temp_RBv", "value"), ("Temp_SP", "set point"),
"Temperature", interval=2.0).start()
```

Note that you will need to restart the entire python session (using the red square) to reload any changes to this code. In future we are to associate the graph setting to each configuration so that, when loading a new configuration, it automatically configures the graph and plots the proper blocks.

Structure of PV names For example if you have a PV name given by IN:DEMO:EUROTHRM_01:A01:TEMP, each component has the following meanings:

IN:DEMO: ... instrument

EUROTHRM_01: ... IOC device

A01: ... channel

TEMP ... value

A known issue with the KEPCO IOC for vertical steering magnet (as of November 2020) There was a known issue with the IOC for the VSM magnet, where it did not restore and set the default values when the KEPCO power supply had been power cycled (*e.g.* a power cut). If this happens, the power supply will not be energised and the block “vsm_power” should report “OFF” on the IBEX dashboard. Should you see this happen, go to the OPI and set the values as follows. EMU normally does not require any VSM currents for standard experiments. However, in the case you were running experiments with a finite current on VSM, you will need to set it again after a power cut.

Kepeco Power Supply

Vertical_steering

Configuration

Status: ● On/Off

Mode: CURRENT CURRENT ▼

Setpoint

Voltage: 10.000 V 10.000 V

Current: 0.000 A 0.000 A

Setting voltage and current have different effects depending on the mode.
[Click for more information...](#)

Readings

Voltage: -0.013 V

Current: -0.001 A

Control

Reset and Resend Setpoints

Figure 22: The device screen for KEPCO Power Supply should look like this.

When setting temperature, if you find errors for setting PID parameters on the console If the PID parameters and the “cycle” are stored internally in *e.g.* Julabo A40 or Heliox Mercury, try setting these parameters to “-1” on the tpar file.

B.3 DAE not found

Upon starting IBEX (or SECI), if you see an error message about “ICP not running” and the system unable to connect to the DAE, first make sure that the DAE crate is switched on. If this error still persists, it is most likely that the DAE driver stopped running. In that case, follow these steps:

1. From NDXEMU, do `Windows + R` and start the Run command.
2. Type in: `“mstsc /v:192.168.1.2”`

3. Log in as *****.
4. From the Start button,
National Instruments ⇒ Measurement and Automation ⇒ NI-VISA 5.4.1 ⇒ VISA server
5. If the server is stopped, click on “Start server now”.
6. You may need to stop and restart the IBEX server.

B.4 Data files clear out (do this procedure about once a year)

The folder on `\\emu\Data\` contained all NXS files for easy-access. However, as the number of files accumulated over the years, it significantly slows down the speed for browsing this folder. To resolve this issue, data files older than three years are moved to `C:\Data\Data post-15_3` on the EMU computer. There is a script, `Harvest.ps1`, for automatically doing this task, which should be (manually) ran about once a year to clear out the folder. First, run an elevated Windows PowerShell as an administrator. Move to the folder `C:\Data` and run the command `.\Harvest.ps1`.

B.5 Useful file paths for IBEX/SECI

Here is a list of file paths, which may be useful to find codes and files:

- SECI `SeciUserInterface.exe`
`C:\Program Files (x86)\STFC ISIS Facility\SECI\`
- EMU instrument routine codes
`C:\Instrument\settings\config\NDXEMU\Python\inst\`
- Configuration and component files
`C:\Instrument\settings\config\NDXEMU\configurations\`
- Muon codes (`muon_begin_end.py`, etc.)
`C:\Instrument\scripts\technique\muon\`
- Script definitions for ScriptGenerator
`C:\Instrument\Settings\ibex_script_generator\scriptdefinitions\`
- Generated python scripts and associated json files
`C:\Scripts\`
- xml files defining the bottom banner of IBEX Client
`C:\Instrument\settings\config\NDXEMU\configurations\banner_xml\`
- tpar files for IBEX
`C:\Instrument\settings\config\NDXEMU\configurations\tpar\`
- Scripts for calibrating ZF compensation system
`C:\Instrument\scripts\technique\muon\zero_field_setup.py`
- For defining a new macro in an IOC, do it in
`C:\Instrument\settings\config\NDXEMU\configurations\globals.txt`
e.g. `MUONTPAR_01__BOOSTER_TPAR_FILE=oxf13_booster.tpar`
- Logs from IBEX can be found here
`C:\Instrument\Var\logs\ioc\`

B.6 Useful commands for Git

Here is some useful commands for Git. A Git Bash window can be opened by right-clicking on a folder in Explorer.

- For browsing a file history,
`git log [filename]`
- For viewing a previous version on the Bash window, get its commit id from `git log` and
`git show [commit id]`