HOW-TO-BNMR EXPERIMENT

TRIUMF

(BC) Vancouver

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Contents

Chapter 1

Introduction

[1]β-detected NMR is an exotic form of nuclear magnetic resonance (NMR) in which the nuclear spin precession signal is detected through the beta decay of a radioactive nucleus. It takes advantage of the new world class radioactive ion beam facility (ISAC) located on the campus of the University of British Columbia. We have recently developed a beam of low energy hyperpolarized radioactive nuclei for applications in condensed matter using an optical polarization scheme. The nuclear method of detection along with the high degree of spin polarization means that βNMR at ISAC is about 10 orders of magnitude more senistive than a conventional NMR experiment. The beamline and associated instruments are unique in the world and open a new window into the magnetic and electronic properties of ultrathin films, nanostrucures and interfaces.

This document summarizes the How-To of BNMR experiment. Contributions are made by group members and topics are intended to be used as guide-lines during the beam-time periods.

[1]Copied from the bnmr website. A general introduction is in preparation.

Chapter 2

Beam tuning

2.1 How to tune the beam

[1]Tuning the beam to optimize its position and size is the preliminary step in performing any βNMR or βNQR experiment. A stable, well-centered beam that does not "wander" if the field (or high voltage on the platform side) are changed is pivotal. Moreover, if experiments are planned to be performed in "fast-switching mode", a good tune at both stations is essential. The degree of tuning at the stations depends highly on how the beam is behaving upstream of the spectrometers; adjustments of elements will vary from beam period to beam period. Tuning is best performed in the ISAC Control Room, as it is the Operators who are permitted to change settings of elements along the beam-line (some are better at this than others). In a perfect world, this procedure would be automated; by saving and re-loading beam-line element settings a good tune for both stations could be quickly achieved. In practice however, tuning takes some time. There is no clear step-by-step procedure for tuning the beam [2].

[1]Written by Terry Parolin

The following must be prepared before beginning to tune:

1. Sapphire scintillators must be in place at both stations; the CCD camera program must be opened [on a terminal in the ISAC Control Room (ssh to bnmrpc) and outside in the hall].

2. Strip tool utility should be running and the counter (ILE2) scalers plotted:

Channel	Counter
S4	b-NMR backward
S5	b-NMR forward
S9	polarimeter left
S10	polarimeter right
S11	neutral beam monitor (nbm) forward
S12	nbm backward

3. The Laser Optics page of Epics should be opened showing the βNMR asymmetry (should also be plotted on the strip tool).

4. Set the high field side magnet to 0, and the high voltage to 0, and EL3 to 0.

2.1.1 General Procedure for Tuning

It is recommended that one starts tuning on the βNQR (low field side), especially if the experiment is to be run in dual-mode. Theoretically, the slits should be set to 7 mm during tuning (as this is a theoretical value, it may not always be the optimal setting).

NQR (low field side)

1. (a) Have the operator set all elements after the polarizer to their theoretical values to start. (b) Set B21 and B3 to their theoretical values– these are not to be changed.

2. Optimize the count rate on the polarimeter side first. This involves adjusting the

voltage on the south plate of XCB2*.

3. With the operator's guidance fine tune the other elements of the b-NQR segment to optimize the beam spot. (Use the camera to image it and be sure to save the best and/or final spot as a benchmark.)

NMR (high field side)

1. Switch to the platform side and again optimize the rate by adjusting the voltage on the north plate of XCB2.

2. With the operator's guidance fine tune the other elements of the b-NMR segment to optimize the beam spot and Forward counter rate (only the F, not the B or the asymmetry). (Use the camera to image it and be sure to save the best and/or final spot as a benchmark.)

3. Test the settings of the tune by ramping EL3 up to 20 kV (no field!). Image the spot frequently to be sure it does not move.

4. Test the settings of the tune for various values of the magnetic field. EL3 should be around 20 kV for magnetic fields less than 3 kG, and maximally 6 kV for higher fields but with the ring electrode at 500 V. The field helps to focus the ions and the electrons; the spot should now become more focused as a result.

8. Image the spot for a fixed value of the field and various values of the high voltage. As the bias is increased the spot will become more diffuse, but should not move (and begin missing the sample).

Bure sure to make careful notes in the logbook of the behavior of the beam throughout the tuning. Use the 'screen capture' utility to print images of the beam-spot to fix in the logbook for various settings. The operators can save tunes (beam-line element settings) and re-load them. When a good set of parameters are obtained have the operator save them before making further changes/testing them. Be sure to record the name of the tune in the logbook. All tunes are named in the following manner

<YYMMDD-time.snapitwbn #r>.

* Ideally the voltage set on the south and north plates should be the same, but in practice the south plate is usually 300-500 V higher.

2.1.2 Criteria for Good Tunes

On βNMR, once the F count on the platform has been maximized and the tune tested, put the hole exposing the sample in place and push the sample into the middle of the magnet. Watch the ratio of the platform F/B count. The F count should still be maximal, and the ratio (at a field of 4.1 T) should be 2. For other values of the field, the value of the ratio may be slightly different; however the F count should always be the largest. At low fields (0.5 T or less) the F count rate should again be maximal and the B rate may fall to a very low value. The ratio of F/B may be as high as 10.

On βNQR Both the L and R count rates should be maximized. The ratio will be approximately 1. To truly test this, put the shutter in the front of the laser and check the rate in the absence of nuclear polarization [2].

2.2 Conditioning the High Field Platform

[2] -Make sure the vacuum space is well pumped.

-Lock up the platform and energize the HV power supply.

-Check that the Current Potentiometer on the HV Supply is set to below 1 turn The current setting is 0.83 turns, corresponding to a current limit of about 0.25 mA (read via needle or via epics).

-Start a strip tool of the HV voltage, current and vacuum (IG3).

-Set the BIAS to 30 kV and condition.

[2]Written by Zaher Salman

2.2.1 Method A

The bias will trip and should stabilize at some low value like 10 kV but at the current limit 0.260 mA. Under these conditions there is a plasma being formed somewhere, and you are conditioning provided the HV is slowly creeping up, e.g. 1kV/10 minutes. Watch the voltage increase, and if it does not continue to improve, then you are no longer conditioning. In this steady-state current limited mode, once you get to xx kV, the bias will hold 30 kV. The ion gauge is affected by this plasma.

2.2.2 Method B

-Turn the current limiting pot to some low value.

-Test the conditioning. Set the set point to some low value (5kV) and wait a moment for the plasma to dissipate (and the current to drop to microamps). Slowly increase the voltage to test if it will hold.

-Repeat the procedure w/ the solenoid on and at field.

-Repeat the procedure with the solenoid and EL3 on.

-Tuning Alkali-Metal Ion Beams Through the Polarizer[1].

2.3 Sodium Handling at the LEBT Polarized Beam Line at ISAC

[3] Unpolarized 8Li+ or other alkali-metal ion beams are neutralized in a sodium vapor cell, with typically 50% efficiency (although over 90% efficiency is possible at high Na vapour densities). The jet-type cell construction, which minimizes the cell length while efficiently trapping the sodium, is shown in Figure 1. Sodium vapor flows from

[3]Prepared by Phil Levy, July 10, 2003

the reservoir, which is typically at 390 C, through a pipe and nozzle, at about 410 C, forming a jet target that is condensed by a collector, which is at less than 175 C. The liquid Na drains under gravity back to the reservoir, through a trap also maintained below 175 C. The relatively cool trap prevents the backflow of vapor from the reservoir into the condenser, since the vapor pressure of Na is negligible below 175 C. The heater leads to the reservoir and nozzle are water-cooled. The collector and trap are air-cooled. The air flow rate is controlled by manually operated metering valves. A previous active feedback system on the air cooling has been removed.

2.3.1 Loading and installing the sodium cell

Sodium reacts vigorously with water, via the reaction 2Na + 2H2O -¿ 2NaOH + H2, so some precautions need to be taken in handling it. If the above reaction occurs in air, the evolved hydrogen will often ignite explosively with oxygen. When disposing of large amounts of Na metal it is also possible for enough heat to be generated to ignite direct oxygen burning of the sodium. In spite of this, our previous experience with I4 shows that water in small amounts is the preferred reagent for disposing of waste sodium. The hazard is greatly mitigated by the fact that most of the Na is recycled and relatively small amounts are disposed of.

The reservoir is initially loaded in a nitrogen-filled glove box with about 100 gm of solid sodium, taken from a sealed stainless steel storage container. A stainless steel knife is used to cut the sodium, which has the consistency of hard cheese. The reservoir is plugged and taken over to the ISAC beam line. It is there unplugged, and attached to the previously cleaned and assembled remainder of the Na cell, then inserted into the beam line, which is then quickly pumped down. Slight oxidation of the Na in the reservoir during this procedure is not important.The beam line is to be purged with dry nitrogen if it is necessary to preserve the sodium while working on

an open beam line.

2.3.2 Servicing a used cell

A used cell needing servicing is cooled to room temperature and vented with dry nitrogen. The amount of Na residue to be cleaned is minimized by cooling the reservoir first to ensure that most condensed Na returns to the reservoir. The cell is then removed from the beam line, and the reservoir is then quickly removed from the rest of the cell and plugged. This minimizes oxidation of the useful Na metal left in the reservoir. The rest of the cell is taken over to the ISIS area and disassembled and cleaned in the fume hood..The Na metal is disposed of by spraying a fine mist of water on it. The fume hood must be clear of all inflammable materials, and the worker must wear a lab coat, eye protection and rubber gloves.

2.3.3 Servicing a contaminated beam line

Small amounts of Na will deposit on beam line components close to the sodium cell after a day or more of operation. This sodium will rapidly convert to NaOH on exposure to the atmosphere and can be wiped away with wet Kimwipes, after removal of the Na cell. Heavier deposits will be seen after several weeks of operation. These can be removed, in situ, by cautiously spraying a fine mist of water on them and wiping up the resulting NaOH solution with Kimwipes. The worker must wear a lab coat, eye protection and rubber gloves.

2.3.4 Sodium cell interlocks

The sodium cell heaters cannot operate if vacuum is lost, water cooling to the cell is off, or the collector or trap temperatures rise above 175C. The reservoir heater goes off

if the reservoir temperature rises above the nozzle temperature, otherwise the nozzle could clog up with condensed Na. The trap and collector temperatures are measured by two thermocouples. The interlocks latch and must be reset by the operator before the heaters can be switched on again.

The sodium cell bias (up to 10 kV) cannot be applied unless the high voltage enclosure is properly installed and the beam line is under vacuum. Once the enclosure is locked in place using two keys, the keys are removed from the locks and inserted into a transfer unit. The master key can then be removed from the transfer unit and inserted into the key switch. Turning the master key in the key switch closes the interlock circuits to the HV and isolation transformer power supplies. It is not physically possible to turn the enclosure lock keys without the enclosure in place

2.4 Tuning Alkali-Metal Ion Beams Through the Polarizer

[4] The polarizer neutralizes a fraction of the ion beam at the Na cell neutralizer, polarizes the resulting neutral beam with laser optical pumping, and then re-ionizes a fraction of the neutral beam at the He cell re-ionizer. The ion beam not neutralized at the Na cell cannot be polarized, and is therefore removed by the deflector plate ILE2:DEF15C onto Faraday cup ILE2:FC15. The fraction of neutral beam not re-ionized at the He cell goes straight through the bender ILE2:B21 into the neutral beam monitor. The Helmholtz coils controlled by ILE2:SOL15A are essential to producing polarization. Preserving polarization to the neutral beam monitor also requires that ILE2:SOL15B is on.

Tuning procedure:

[4]Prepared by Phil Levy, July 3, 2003

1. Make sure that the polarizer is completely off i.e. beam line components ILE2: BIAS15, RESEVR, NOZZ, DEF15C, SOL15A, and SOL15B are all off, the Na cell reservoir and nozzle temperatures are both below 200 deg C, and ILE2:FG16 (helium flow) is set to zero.

ii. Tune stable pilot ion beam through the polarizer to the experimental target. The smallest restriction in the polarizer is an 8 mm diameter aperture at the entrance to the He cell chamber. Because of that restriction, the best transmission through the polarizer of a 30 keV ion beam is about 82%.

iii. Turn on the helium flow (typically 1.0 ccm). This will increase the emittance of the ion beam. Slight retuning of elements downstream of the He cell may be required.

vi. Turn on ILE2:SOL15A (typically 5 amps). This should have no effect on the beam tune, since the magnetic field is small (∼10 gauss) and along the beam axis. If required by the experimenters, turn on SOL15B as well (typically 10 amps). This will move the beam slightly in the vertical direction at the bender ILE2:B21 and will probably need correcting downstream of that. You have then finished tuning the unpolarized ion beam.

v. Now turn on the deflector ILE2:DEF15C. Typical value for 30.6 keV beam is 1926 V. The value should scale linearly with the ion beam energy and be independent of the isotope mass. The ion beam current can be measured at ILE2:FC15.

CAUTION: Oversteering the beam can lead to high radiation fields when running radioactive beam.

vi. Turn on the Na cell.Typical reservoir and nozzle temperatures are 470 and 480 deg C, respectively. The nozzle must be turned on first, so as to keep it hotter than the reservoir, otherwise an interlock will shut off the reservoir heater. The trap and collector, ILE2:TRAP and: COLL, are passively air-cooled and only read back temperature (a previous closed loop control has been removed). As the Na cell heats

up, one sees a decrease in the ion beam current at ILE2:FC15 and an increase in ion beam current after the He cell. At typical operating temperatures and He flows, the overall transmission efficiency of the polarizer is ∼30- 40 %.

vii. Turn on the Na cell bias ILE2:BIAS15. The experimenters should know the approximate setting. The final ion beam energy is decreased by that amount.This requires decreasing the voltage on all electrostatic elements downstream of the He cell by a percentage equal to the percentage decrease in beam energy.

NOTE: the bias only reduces the energy of beam that is neutralized within the Na cell. Any ion beam passing through is re-accelerated at the Na cell exit to the initial energy, albeit with worsened emittance, since there are nice field-shaping electrodes only at the entrance to the Na cell, none at the exit.

viii. Switch over to radioactive beam.

2.5 Calibration

2.5.1 Conversion field-current

[5]The conversion between the field H in G and the setpoint current I in Amps is

$$H = A + BI, \tag{2.1}$$

where A=0.175±0.046 G; B=2.2131±0.0019 G/Amp.

2.5.2 Conversion from Band Width to Pulse Duration

ln-sech Pulse Tp[msec] × BW[Hz]=$5.10^4/\pi$

Hermite Pulse Tp[msec] × BW[Hz]=1764.8.

[5]Done by Zaher *et al.*

Chapter 3

Alignement of the cryostat

In this chapter we describe how to align the bnmr cryostat using the flashlight and telescope, use camera, and view the pictures with special software.

3.1 With Flash light

[1] We have noticed that the cryostat dis-aligns each time after mounting a sample. So, it is very practical to take a flash-light picture after each mounting to make sure that the cryostat did not move. To do that place the flash-light in-lieu of cover of the hole close to the telescope. Connect the camera to the computer with appropriate wire (labeled BNMR). Take a picture of the cryostat with the flash-light on, and see if the sample holder is in the middle of the bright flash-light circle (black circle as in Fig. 3.2-a). If it is shifted from the center, then adjusting the cryostat is mandatory. Loosing or tightening the screws of the cryostat is the way to get it centered (see Fig. 3.1). The screws to adjust are shown in Fig. 3.1, and rotating the top or bottom ones (there are two small ones in front and two in the bottom with a square drive) in 45^o

[1] Written by Hassan Saadaoui

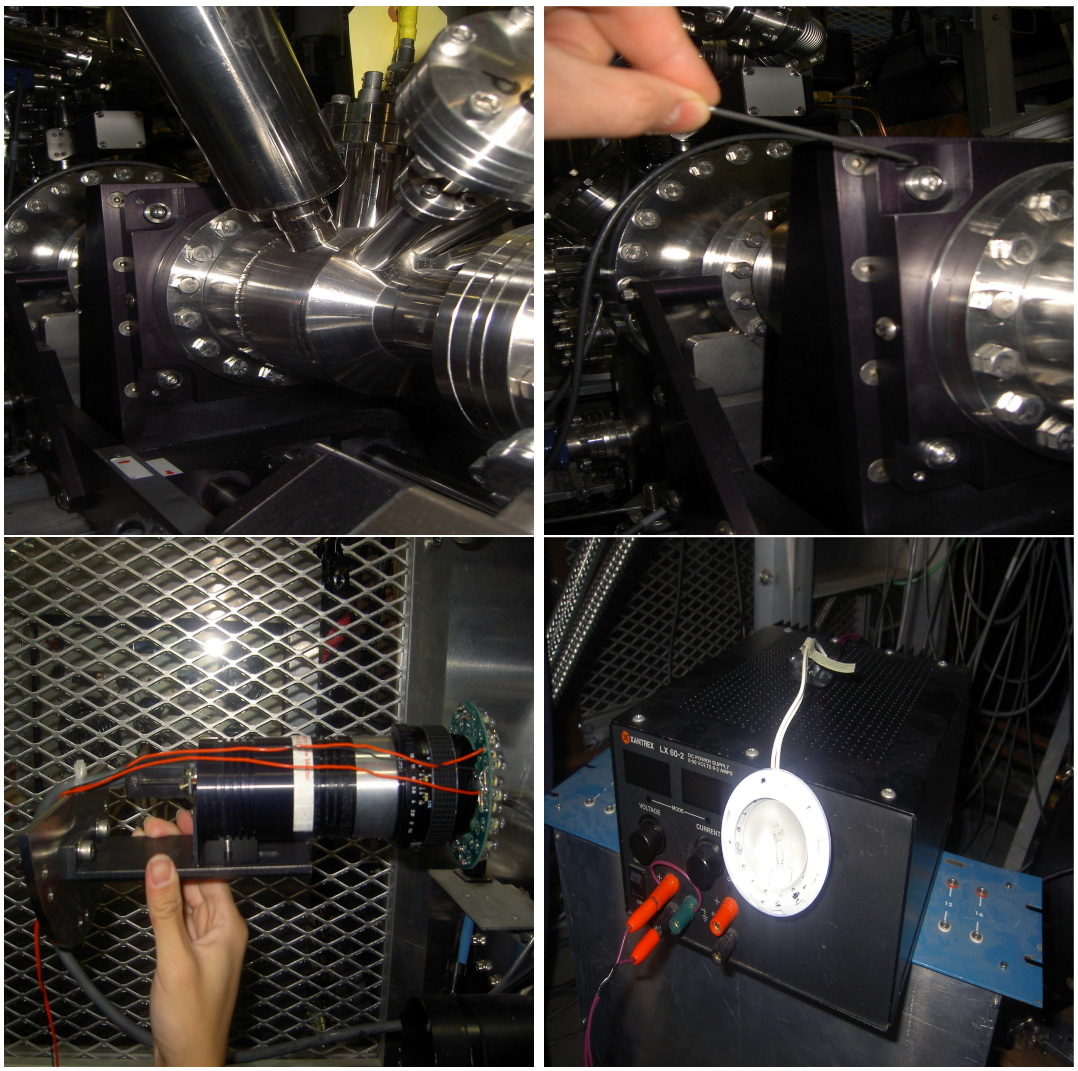


Figure 3.1: (a) Cryostat position, (b) Allen wrench adjusting the top-right screw of the cryostat alignment, (c) CCD camera, and (d) Halogen lamp used in lightning the Cryostat with its DC power supply.

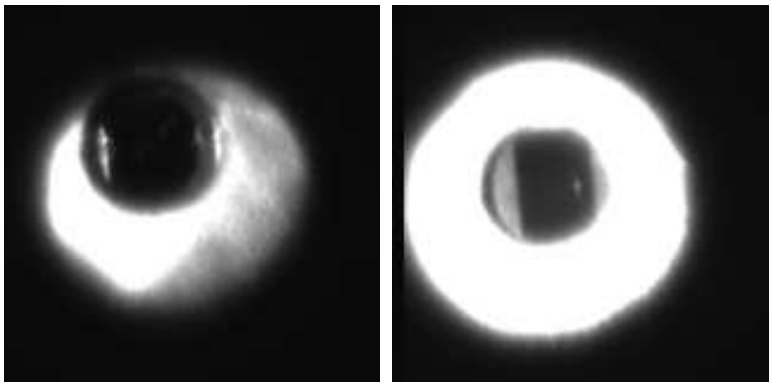


Figure 3.2: (a) Bad and (b) good alignment of the cryostat

using an Allen wrench (4/16 size) is enough to make the cryostat move up or down (3-4mm). Take a picture after each adjustment, and be only satisfied once you get a picture similar to Fig.3.2-b. A more robust and time consuming way would be using the telescope, which is explained next.

3.2 With the telescope

To adjust the cryostat position with telescope, at least two people are needed. One has to watch the cryostat position using the telescope, while the second person has to adjust the cryostat position and communicate with the viewer by a "handy-phone". First, change the position of the cryostat to Al position which has a specific pattern with concentric circles and a dot in the middle. Take out the CCD camera, and use instead the Halogen lamp (works with 12V, so use a DC power supply, model Xantrex LX 60-2, and set it first to 12 V with a digital voltmeter before connecting to the lamp). Place in the Halogen lamp instead of camera, and make use of telescope to see the hole of the cryostat centered. Make sure that all the valves between the telescope port and sample are open. Adjust the screws of the cryostat as before if needed.

Here are some troubleshooting points that may help

- Check if the LED are on or off.
- Check if the cables are connected to the camera.
- Check if all sources of light are closed.
- Check if ion gauges are closed.
- Make sure the Faraday cups are open.

3.3 How to use cameras

[2] There are two CCD cameras, one for BNMR and one for BNQR. They can be used by imaging the beam spot or the sample position to (i) tune and center the beam on the sample for either BNMR or BNQR, (ii) align the BNMR cryostat, and (iii) align the sample on BNQR side. These cameras use "peltier cooler" to actively cool the CCD down to -30^o, in order to minimize the background noise. The camera needs a 12V DC power supplied through a USB box. The USB box also provides the data link from a camera to *bnmrpc.triumf.ca*, where the cameras are controlled and operated. Only one camera which is connected to the USB box is active. In order to activate the other, one has to switch the cables connected to the USB box. Note: Do not switch camera cables while the computer program used to operate the camera is running. First close the program and only then switch the cables and restart the program again. If you do not follow this procedure you will have to reboot *bnmrpc.triumf.ca* to get the cameras running again.

For extra light a set of LED lights mounted on both cameras is used to provide lighting if needed. In order to turn on these LED you need to connect their power supply.

[2] Written by D. Wong

3.3.1 Focusing the camera

The procedure for focusing the camera BNMR and BNQR is very similar. For example, the BNQR camera is mounted on the upper semicircular plate (shown in the picture below) and well focused on the sample position with these settings: (i) Focus setting 0.67m, (ii) Aperture wide open, and (iii) The F number is 1.4. When refocusing start with large F number=16 which gives you better depth of field, and may help you find the right focus settings. The camera lens can be accessed through a small window(Access port), shown in the picture below

3.3.2 Taking an image

1. Choose which camera to use by plugging its cable into the USB box.

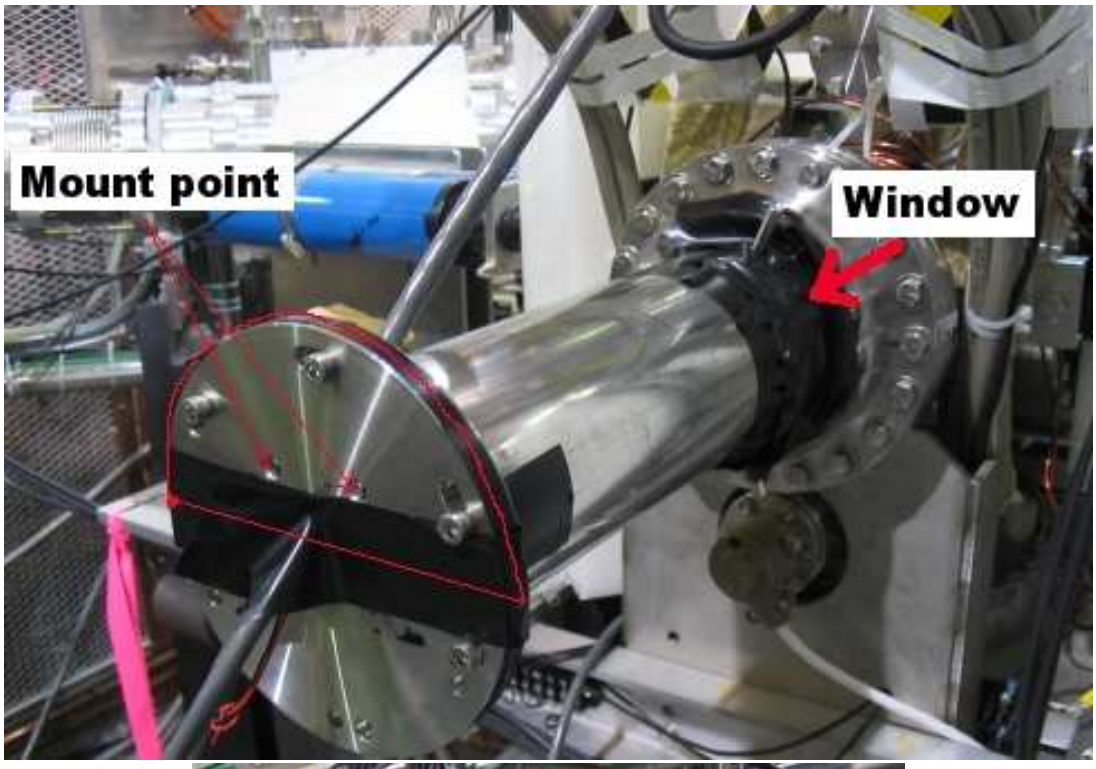
2. Turn on the 12V DC power (shown in the picture below), its indicator will turn yellow. It takes about 15 minutes for the CCD cooling down to about -30 Celsius (but you do not need to wait this long, you may start immediately). Remember, you must turn off the camera control software on *bnmrpc.triumf.ca* before you switching the cables.

3. If you need more light turn on the LEDs. Remember to turn it off before you continue your experiment.

4. Turn on the camera control software on BNMRPC by left clicking the 500MX icon on the desktop. If it is already on and can't find the camera, you have to reboot the computer.

5. Choose the right scale for BNMR camera or BNQR camera. **6**. Check exposure time before a shot. Normally 0.1 second with LED and 30 seconds without LED.

7. To get an image, click the START button. If the shot is not clear, choose stretch line from the Option menu of the software. If it is not improved, adjust the exposure



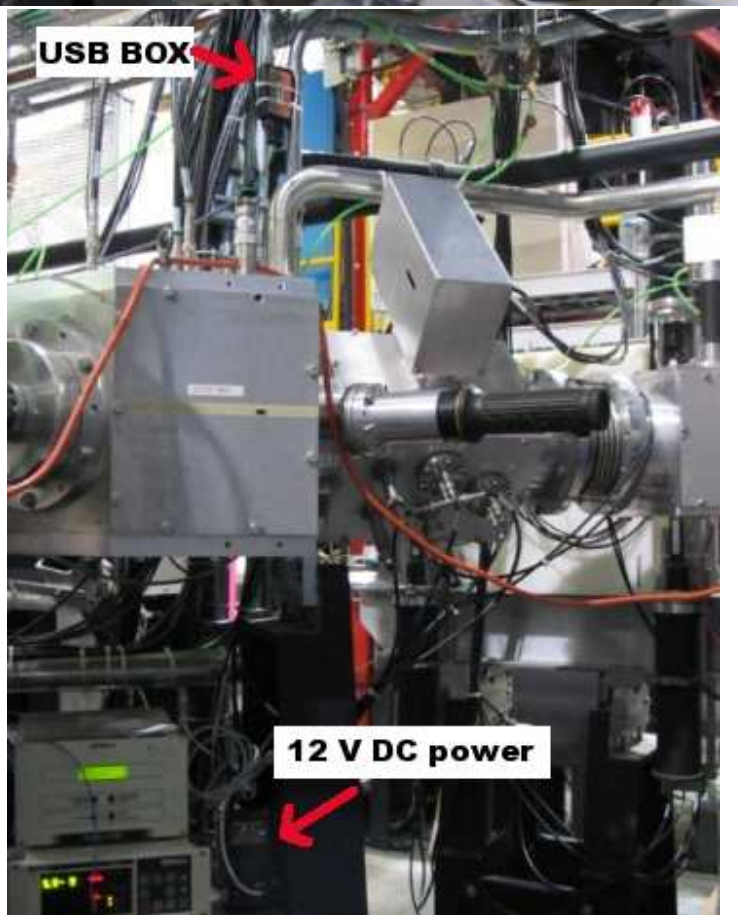


Figure 3.3: (a) BNQR camera and access window. (b) USB box and 12 V DC power

time.

8. Moving the mouse to the position of interest, e.g.the center of the beam spot or sample position, the software will show the coordinates of the position. You can record up to 11 coordinates for later reference.

9. If needed, save the shot to the BNMRIMAGE folder on the desktop for later reference, you may need a new subfolder for every experiment.

10. Need a new image repeat steps 7,8,9.

11. Make sure the LED is off before you continue your experiment.

3.3.3 Remote control

You can remotely control bnmrpc.triumf.ca using VNC viewer. You may need to start the VNC server on bnmrpc first. Thee in a console, just type

vncviewer bnmrpc.triumf.ca

You will be prompted for a password (which you should know) and then get the bnmrpc desktop in a window. Normally for tuning the beamline, you open a vnciewer on bnmrpc from the control room.

Chapter 4

Hardware and spectrometers

4.1 RF system

4.1.1 Low RF system on platform

[1] In order to generate the RF frequencies used in BNMR/BNQR, the signal synthesized by the PSM must be amplified to the required power, but these amplifiers only work over a specific frequency range. There are two amplifiers: a high frequency which operates between 250 kHz-80 MHz, and a low frequency amplifier which operates over 10-500 kHz. There is also the DAC attenuator on the platform (the blue box located at "a" in Fig. 4.1) has its own operational band width different from the amplifiers. This causes this attenuator to behave non-linearly at low frequencies resulting in less power than expected being delivered to the RF circuit (cct). It has been observed that this effect is taking place for frequencies around 630 kHz (the Larmour frequency for an external field of 1 kG). The blue box is an attenuator that protects the RF cct at the sample from receiving too much power, and therefore one should take caution when removing this element as the cct is no longer protected without it. The first step

[1] Written by T. Keeler

Figure 4.1: (a) Location of the DAC system on platform, (b)Attenuator, and (c) Load.

in going to low frequency is to start a 1f "test run" at high frequency (say f=21-21.01 MHz) with maximum power (ie: PSM=255, DAC=1540). Once the run is started measure the peak to peak amplitude on the oscilloscope ("b" in Fig. 4.1) from the FWD output of the "bidirectional coupler" (located at "c" in picture, and shown in detail below). This peak to peak amplitude is the maximum that can be sent into the RF cct without damaging it. Once this is measured it is a good idea to stop the test run to stop the RF. Now, disconnect the 50 Ohm load(located at "d" in Fig. 4.1) (which is normally connected to the output of the RF cct), and connect to the "output" of the bidirectional coupler (the output is normally connected to the RF cct input in the spectrometer). This is to disconnect the RF cct while bypassing the DAC attenuator.

Now, connect the output of the amplifier, "e" in Fig. 4.1, (which is normally connected to the DAC attenuator input) directly to the input of the bidirectional coupler (which is normally connected to the output of the DAC attenuator). Now connect the PSM (wire that is labeled "PSM", and will be connected to the amplifier input) to the input of the "clicker" manual attenuator (located at "f" Fig. 4.1), and the output of this attenuator to the amplifier input. By doing this you have bypassed the DAC attenuator, and added manual attenuation. Now, start another 1f test run over a range of low frequencies (ie: 300-310 kHz) and PSM=255. Again, measure the peak to peak amplitude on the oscilloscope from the FWD of the bidirectional coupler, and add attenuation (by flipping the switches on the manual attenuator) so the the peak to peak amplitude does not exceed the amplitude measured at high frequency. Now you can reconnect the RF cct by reconnecting the its output to the 50 Ohm load, and the input to the output of the bidirectional coupler. To go to frequency regimes lower than the 250 kHz limit of the high frequency amplifier (for fields on the order of 1kG, for example), you must replace this amplifier with the low frequency generator

Figure 4.2: Turn off this BNMR RF Amplifier.

from the BNQR side. The rest of the procedure is the same, but "amplifier" will refer to the low frequency amplifier. The key in this procedure is to error on the side of caution with attenuation, as burning out the RF cct in the spectrometer will severely disable the experiment for the rest of the run, not to mention you will be severely disabled after Syd gets a hold of you!

4.2 Detectors

How to turn on the detectors, check signals and check discriminators and trouble shoot electronics? We need an electronics diagram showing the detectors, disc fanouts, optical links and Multi channel scalers? This task is in preparation.

4.3 How to shutdown the equipments

(See the figures by order)

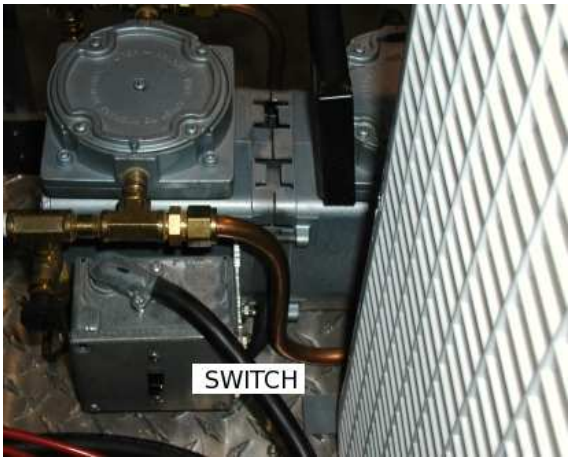


Figure 4.3: Turn off the mass flow pump on platform as well as dark yellow valve.

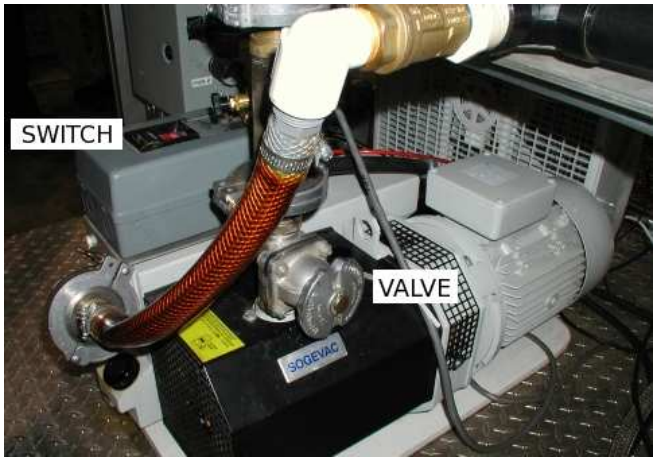


Figure 4.4: Close the valve of the SOGEVAC pump, and turn off its power.

Figure 4.5: Turn off HV of the BNMR Forward detector (A).

Figure 4.6: Turn off Lecroy HV power system it is for BNMR back detector,BNQR left and right detector. It also powers the neutron beam detector

Figure 4.7: Turn off BERTAN HV power supply, it is used to apply a 500V on a ring electrode in the Einzel lens of EL3.

Figure 4.8: Turn off the BNQR RF amplifier

Figure 4.9: Close the valve of the pump for BNQR

Figure 4.10: and turn its power off

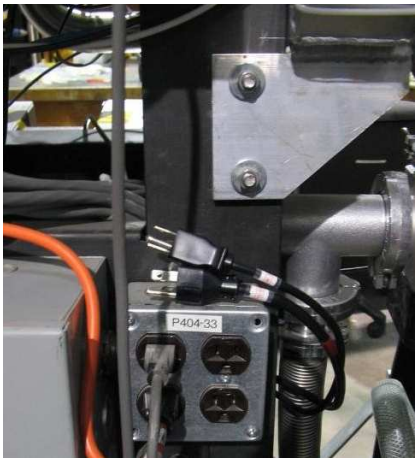


Figure 4.11: Turn off the switch box of the South and the North bender

Chapter 5

Changing and aligning samples

5.1 Changing and aligning samples on the βNQR

5.1.1 Changing samples

You must know the position number of the sample of interest before commencing a sample change. The order of samples should typically be noted in the bNQR logbook at the start of each beam period by whomever loads the ladder.

1. The samples are mounted on a "ladder," and as such are arranged vertically. A rod is attached to the top of the ladder and extends out of the cryostat; it is topped off by a black knob. The distance 'D' between the bottom of the upper portion of this knob and the topmost segment of the cryostat determines which sample is located in the path of the beam; see Fig. 5.1.

2. Ask the control room to place a beamstop (Faraday cup) upstream of the NQR cryostat before beginning the sample change. Sample changes should not be performed unless the temperature is at least ???K.

3. Carefully climb the stairs beside the cryostat so the rod and knob are within reach.

4. The ladder is secured in place (and makes thermal contact with the cryostat) by

means of small wings attached to the sides of the ladder at the sample positions. Turn the black knob 1/4 turn counterclockwise (to the left looking down on the knob) to release the wings.

5. Adjust the height to the rod (up of down) such that the new D corresponds to the new sample position of choice (a measuring tape is required for this).

6. Turn the knob (i) clockwise [or (ii) counterclockwise] to reseat the wings and secure the ladder in the new position. If it is turned (i) the side of the sample facing the beam will be the same as before. If it is turned (ii) the side of the sample facing the beam will be the reversed from before. This is important because often the sample ladder is loaded in such a manner that at some positions the sample is different on each side, e.g., Au foil wrapped on sapphire; Au foil when facing one side, or sapphire when facing the back. (red tape / masking tape for this front/back choice???)

7. The sample has been changed, but may not be sufficiently aligned. Instructions for the alignement are given next.

5.1.2 Lateral Alignment

1. The beam spot should impinge on the sample normal to its surface (unless it is desired that the beam spot (i.e., the Li polarization) and sample surface be at angle with one another.

2. To correct for any misalignment between the surface of the sample and the beam, first have the beamstop removed so that radioactive beam is being delivered to the sample (do not linger around the spectrometer more than necessary). Second, on the EPICS laser control page, close the shutter to the laser. This will result in unpolarized Li being delivered to the sample.

3. The lack of nuclear polarization means that there should be no significant asymmetry in the count rates now, unless the sample is not parallel in the plane of the

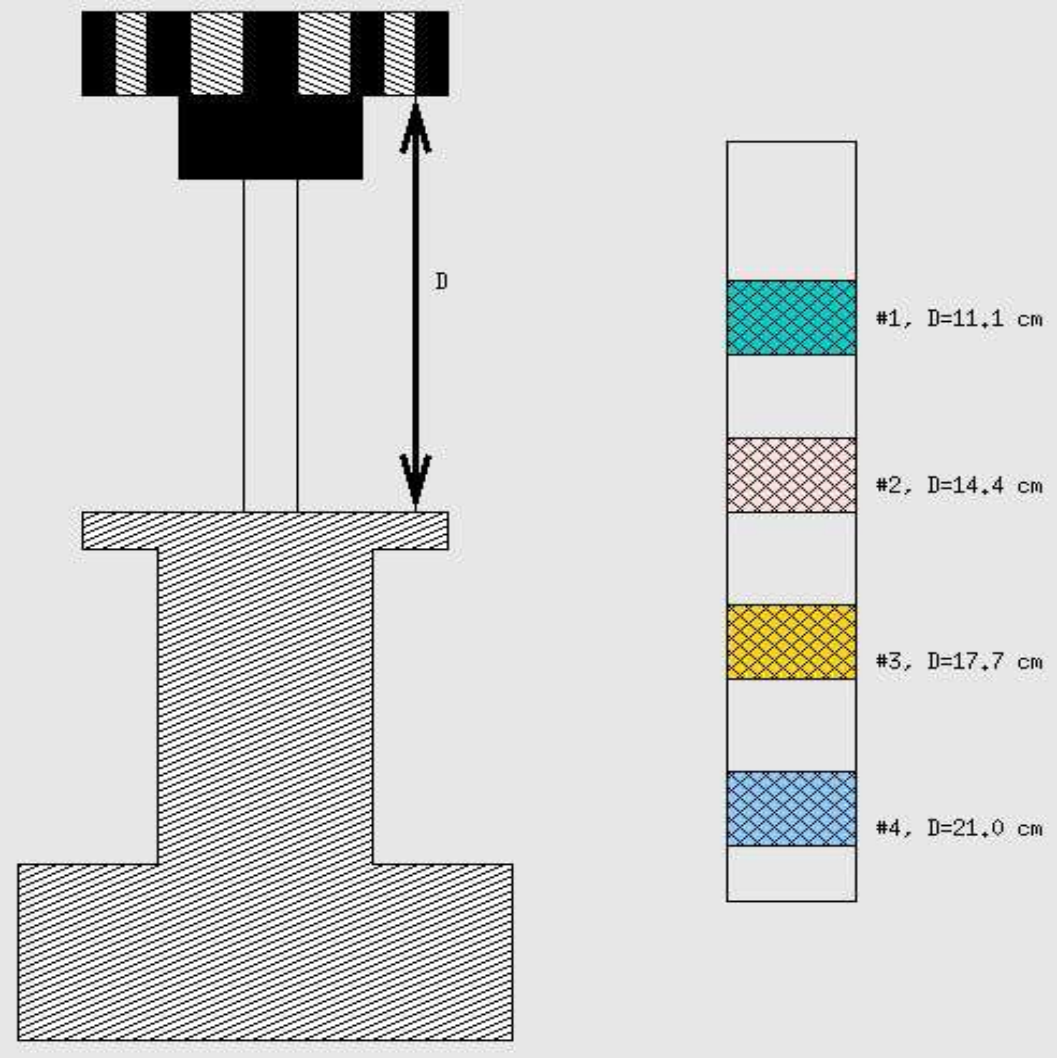


Figure 5.1: Schematic showing the distance between the top of the sample ladder and the mouth of the cryostat used to select whcich sample is placed in the path of the beam.

two counters. Read the L/R count rates from the visual scalers, or the strip tool and compare them to each other and the neutral beam monitors.

4. If there is a significant asymmetry in the absence of polarization, rotate the black knob slightly, left or right, to try to find a position which equalizes the rates in the 2 counters. Minor adjustments; otherwise the wings of the ladder will become disengaged with the cryostat.

5. Remove the laser shutter and have the beamstop replaced during vertical alignment.

5.1.3 Vertical Alignment

1. Use the CCD camera (βNMR-MX5; see section **??** (INSERT LINK TO ON LINE CAMERA MANUAL HERE)) to obtain an image of the back side of the ladder at the sample position (be sure that the program is receiving the signal from the polarimeter camera). The torus of LCD lights surrounding the camera will probably need to be illuminated to provide sufficient background light for an image. Or, the cover plates at the end of this section of the beam line may be removed to introduce ambient light. Using the photometry tool (View ¿ Photometry) determine the (x,y) co-ordinate that corresponds to the center of newly loaded sample.

2. Open (File $->$ Load) the most recent stored image of the polarimeter beam-spot taken with sapphire in the sample position (see below). Using the photometry tool determine the (x,y) co-ordinate that corresponds to the center of the beam spot. Elements of the beam line may be 'tweaked' during the course of experiments, so be sure to use the most recent image. The co-ordinates of the center should also be recorded in the bNQR logbook. [If you are unsure of the exact co-ordinates, you may want to place the sapphire in the sample position (part A above), have the beamstop removed, and image the beam-spot with the camera (no additional light required).]

3. Compare the co-ordinates for the center of the present sample with those of the beam-spot image. Determine if the sample should be raised or lowered (or neitrher) relative to the beam-spot. Using the remote control for the motor, drive the entire cryostat 'UP" or 'DOWN' as desired. Small, incremental changes are recommended. (Be careful, depending on the orientation of the CCD camera, UP and DOWN may be reversed!).

4. Re-image the sample after cryostat adjustment and continue to adjust as needed.

5.2 Getting out a sample from βNMR cryostat

If the load lock is under vacuum, vent it through SVV5 (see figure above) note there is a manual valve in line with this automatic valve. Remove the blankoff on the top of the lock by undoing the three bolts with the allan key located on the side of the lock. Keeping the rubber o-ring in place, mount the clean end of the manipulator into the vacuum lock and seal it using the three screws and the allan key. Do not get the manipulator's clean end dirty by touching it with your bare hand for example. Rough out the lock: Go To the Control Room and Get the operator to open up the EPICS page shown above Make sure the vent valve SVV5 is closed Turn on the roughing pump if it is off. (the round black circle BNMRBP5 above should be green) Note the Fuji dry roughing pumps are often switched off due to their short lifetimes If the roughing pump is working the convectron gauge BNMRCG5 should go down to some low value like 50 mT - that's T for Torr Open the valves to the lock: PV5, RVX6 and RV5 You can watch it rough down on the convectron gauges CG6A and CG5D Rough out the backside of the sliding seal:

Ensure the KF25 flexible pumping line is connected to the flange on the side of the manipulator Close RV5 Note typically the lock pressure comes up when you isolate

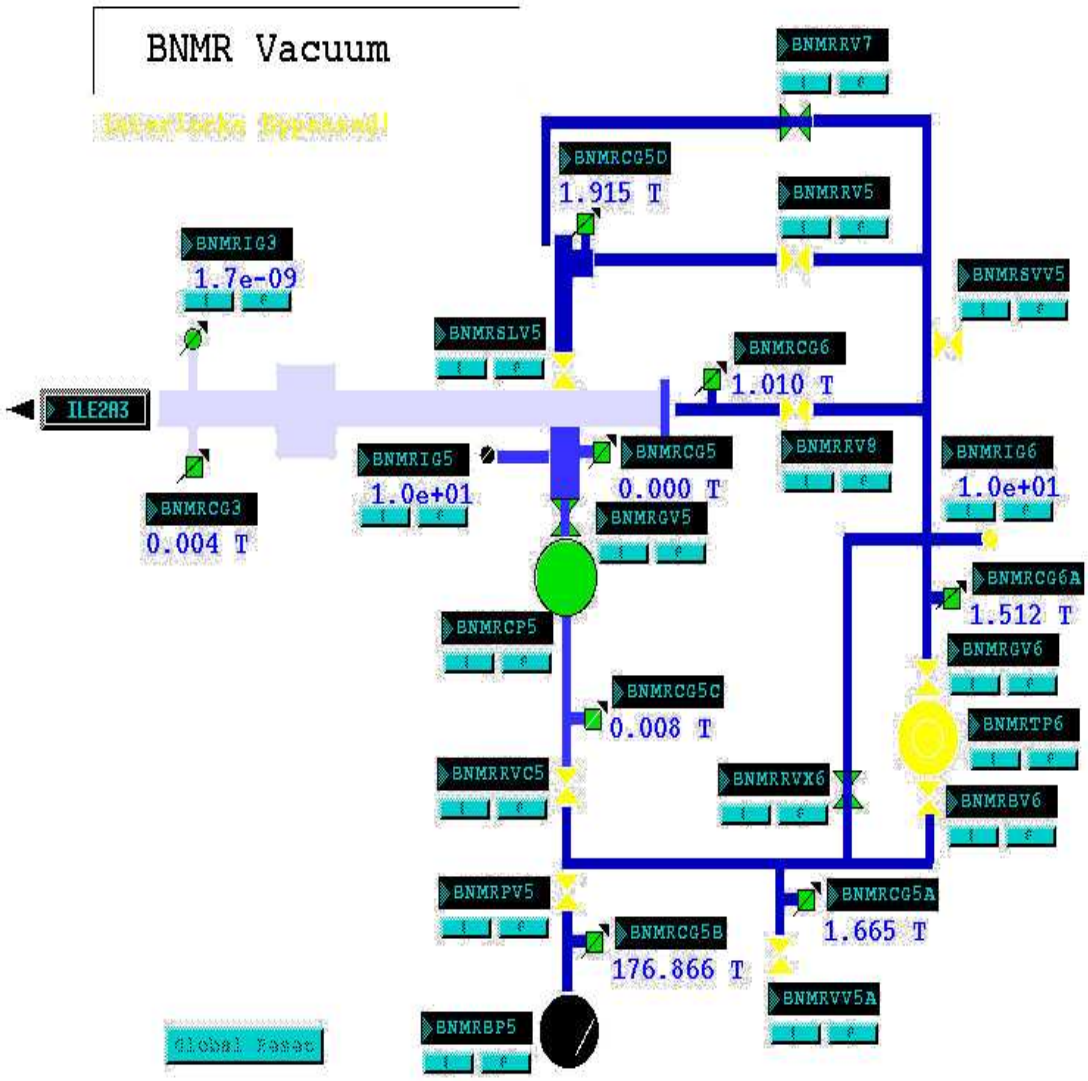


Figure 5.2: Vacuum system

it due to outgassing this can be seen on CG5D Open RV7 Watch it pump out on convectron CG6A Spin Up the Turbo Pump BNMRTP6 - the yellow circle above

You need to back it with the roughing pump first, close VX6 then open BV6 When it is safe, open the inlet side of TP6 using GV6 Pump out the lock and the backside of the sliding seal:

Let it pump for a while, then close RV7 and start pumping on the lock (open RV5) Pump the lock for 15mins The gauge CG5D will quickly bottom out, but After a while you can turn on the ion gauge IG6 at the turbo and watch it come down to a few microTorr Prepare to open the gate valve:

Turn off the ion gauge IG6 to protect it Close RV5, isolating the lock Then QUICKLY open RV7 to pump on the "differential space" at the back of the sliding seal If you are too slow the TP will trip off and you have to turn it back on. Note when the manipulator is going into the UHV space, you must pump continuously on the differential space with the turbo Let it pump for a minute or two Open the gate valve (SLV5) now the lock is open and the UHV is spoiled (not badly if you have followed the above) Go to the platform push the manipulator down, opening the hatch if you haven't already Using the motor and the side-to-side play of the bellows on the lock position the manipulator directly over the threaded hole in the sample holder Unscrew the sample: note this is a reverse thread, so you turn as if you were taking it out (pressenig gently to engage the threads). This is Counterclockwise! Once the reverse thread is fully engaged, the outer normal threads will begin to pull out. Continue turning the same way until the holder is free Retract the manipulator (with holder attached) into the lock all the way

ENSURE the holder is up by using the brass rod to keep the manipulator handle at the necessary height Once this is done, close the gate valve from the control room SLV5 Vent the lock Remove sample and manipulator (without touching the clean end)

Blank off the lock to keep it clean Turn off the roughing pump if you are going to be a while.

5.3 Loading βNMR in an empty cryostat

If the load lock is under vacuum, vent it through SVV5 (see figure above) note there is a manual valve in line with this automatic valve. Remove the blankoff on the top of the lock by undoing the three bolts with the allan key located on the side of the lock. Keeping the rubber o-ring in place, mount the clean end of the manipulator into the vacuum lock and seal it using the three screws and the allan key. Do not get the manipulator's clean end dirty by touching it with your bare hand for example. Rough out the lock: Go To the Control Room and Get the operator to open up the EPICS page shown above. Make sure the vent valve SVV5 is closed. Turn on the roughing pump if it is off. (the round black circle BNMRBP5 above should be green). Note the Fuji dry roughing pumps are often switched off due to their short lifetimes. If the roughing pump is working the convectron gauge BNMRCG5 should go down to some low value like 50 mT - that's T for Torr. Open the valves to the lock: PV5, RVX6 and RV5. You can watch it rough down on the convectron gauges CG6A and CG5D. Rough out the backside of the sliding seal:

Ensure the KF25 flexible pumping line is connected to the flange on the side of the manipulator. Close RV5. Note typically the lock pressure comes up when you isolate it due to outgassing this can be seen on CG5D. Open RV7. Watch it pump out on convectron CG6A.. Spin Up the Turbo Pump BNMRTP6 - the yellow circle above You need to back it with the roughing pump first, close VX6 then open BV6. When it is safe, open the inlet side of TP6 using GV6. Pump out the lock and the backside of the sliding seal: Let it pump for a while, then close RV7 and start pumping on the

lock (open RV5). Pump the lock for 15mins. The gauge CG5D will quickly bottom out, but after a while you can turn on the ion gauge IG6 at the turbo and watch it come down to a few microTorr.

Prepare to open the gate valve: Turn off the ion gauge IG6 to protect it. Close RV5, isolating the lock. Then QUICKLY open RV7 to pump on the "differential space" at the back of the sliding seal. If you are too slow the TP will trip off and you have to turn it back on. Note when the manipulator is going into the UHV space, you must pump continuously on the differential space with the turbo Let it pump for a minute or two Open the gate valve (SLV5) now the lock is open and the UHV is spoiled (not badly if you have followed the above) Go to the platform push the manipulator down, opening the hatch if you haven't already Using the motor and the side-to-side play of the bellows on the lock. position the manipulator directly over the threaded hole in the sample holder. Screw the sample in: note this is a normal thread, so you turn as if you were taking it in (pressenig gently to engage the threads). This is Clockwise! Once the thread is fully engaged, the inner reverse threads will begin to pull out. Continue turning the same way until the manipulator is free. Retract the manipulator (without the holder) into the lock all the way. ENSURE that the manipulator is up by using the brass rod to keep the manipulator handle at the necessary height Once this is done, close the gate valve from the control room SLV5. Turn off the turbo pump, and then turn off the roughing pump.

5.4 Shutting down the βNMR vacuum pumps

1. After completing a sample change(see section 5.3) ensure the loading rod has been moved into the lock and is supported with the brass rod, and SLV5 is closed. (The EPICS page entitled "BNMR Vacuum" should still be open.)

2. Isolate the turbo pump by closing the inlet GV6.

3. Spin down the trubo pump TP6 (i.e., turn it off; it will change from green to black on the display).

4. Once the turbo pump has slowed isolate it from the roughing pump by closing BV6 and PV5.

5. Turn off the roughing pump BP5 (it will change to black on the display).

Chapter 6

DATA ACQUISITION

6.1 How to use ELOG

6.1.1 Starting the Elog

In order to use the Elog you must have the mhttpd daemon running, check logging to bnmr or bnqr account on isdaq01 and type *ps ux — grep mhttpd*. You should get something like:

bnmr 5991 0.0 2.2 25268 23156 pts/2 S Sep30 3:03 mhttpd -p 8081 -c -d

bnmr 12996 0.0 0.0 3588 620 pts/6 S 14:01 0:00 grep mhttpd

If it is not running then type *start_mhttpd*, and now you can browse or edit the elog by visiting the following URLs

i- For nnmr elog: http://isdaq01.triumf.ca:8081/EL/?exp=bnmr

ii- For bnqr elog: http://isdaq01.triumf.ca:8082/EL/?exp=bnqr

6.1.2 Changing the automatic Elog scripts

The script that save an elog entry at the end of each run is online/bnmr/bin/elog_every_run.csh.

Command line to add an elog entry: *melog -h isdaq01 -p 8081 -l bnmr -a author="Dong"*

-a Type="Automatic Elog" -a System="Elog" -a Subject="this is subject" -m filename

To send picture to elog: *melog -h isdaq01 -p 8081 -l bnmr -a author="Automatic Elog" -a Type="Automatic Elog" -a System="Elog" -a Subject="Pic Grab" -f pic.jpg -m /scripts/blank.txt*

6.2 How to startup the standard strip tool

Using strip tool one can monitor EPICS settings/readbacks in convenient graphics window. This is useful for tuning and detecting problems in the experiment (both hardware and software related problems). Here are the steps to start and setup a strip tool:

1. Start EPICS if it is not running already. In a console type: *ssh bnmr@isacepics1*, and then enter the password and you will get the man EPICS menu.

2. On the menu, move your mouse to "Utilities" option, press and hold the right button of the mouse, then select "start strip tool" by moving your mouse on it and release the pressed right button. Now you will get a window named "StripTool Controls".

3. Go to the "File" menu under the "StripTool Controls" window, and select "Load", you will get a "Configuration File popup" window now. Under the "Configuration File popup" window, go to the directory "/home/bnmr/", there are 4 saved configuration files, each contains different variables that need monitoring under different conditions:

bnmr_rates.stp used to monitor count rates at the experiment

bnmr_switch.stp and *bnqr_switch.stp* used for dual mode operation on bnmr and bnqr, respectively

conditioning.stp used when conditioning the bnmr platform.

Load the appropriate one, e.g. *bnmr_rates.stp*, and the name of the "StripTool Controls" window will change to "bnmr_rates.stp Controls" (the Controls window) and the variable names will be listed. These variables are plotted in a new window called "bnmr_rates.stp Graph" (the Graph window). You may modify the range of a variable or add new variable you want to monitor in the Controls window. You may also save you modifications so you can load the modified settings next time.

4. You may add to a strip tool any variables in EPICS which is displayed in blue or green color. To select a variable, move the mouse to the blue colored number and press the middle button of the mouse. A small window titled "dmChan" will appear, with the channel name of that variable. Select this name by pressing and holding the middle mouse button, and drag it to the frame named "Plot New Signal: " in the Controls window, release the middle button and press the "Connect" button on the right of the frame, you will get that variable channel connected and plotted as a function of time in the Graph window. For example, To monitor rates, we use the scalers. These are accessible from the main EPICS page under Experiments and ILE scalers. The names are as follows:

Name	Description	Symbol
S4	BNMR Forward Counter	F
S5	BNMR Back Counter	B
S9	BNQR Left Counter	L
S10	BNQR Right Counter	R
S11	Neutral Beam Monitor Forward Counter	NBF
S12	Neutral Beam Monitor Back Counter	NBB

6.3 How to use Camp

CAMP is used to control and monitor peripherals. It consists of two parts: a SERVER and a CLIENT. The server runs under VxWorks on a MVME162, the client runs on a linux pc. There are two MVME162 machines, one named bnmrvw for BNMR, the other named polvw for BNQR.

6.3.1 To reboot camp

In a console, to connect BNQR camp server type: *telnet polvw*, and to connect BNMR camp server type: *telnet bnmrvw*. Then after the prompt -> type: *reboot*. Then you will see the following words after reboot, *Connection closed by foreign host*. To reboot camp server manually, go to the MVME162 machine reset it.

6.3.2 CAMP Client

Camp client may be accessed by a user in two ways: a Character-cell User Interface (CUI) and a Command-Line Interface (CLI). The CUI is an interactive, menu-oriented interface, which provides with an updating data display. The CLI is intended for use by shell scripts. If your linux machine installed camp or login to isdaq01 by *ssh bnmr@isdaq01*, In a console, type: *camp -node bnmrvw* to get the bnmr camp client GUI. You will see a list of instruments displayed in left window.

1. To make an instrument online, Use the keyboard arrow button select an instrument press ENTER. Under the choose-¿ menu, select online and press ENTER. For example, thermometer /Sample for BNMR, if you get the following message, Instrument connection Setting instrument "/Sample" online... gpib timeout on write online failure: failed ID query, check interface definition and connections. Then the instrument is NOT online. Try to make it online,

1-a. Reset the instrument interface. The interface option is under choose-¿ menu, just above the online option. If it does not work,

1-b. Turn off the thermometer controler on the crate and turn it back on. If it does not work,

1-c. Turn off the whole VME crate and turn it back on.

You should check the address as well.

2. To load an instrument configuration file, Press TAB, under Main menu, select "Configure", choose "Open config file" or "Import (add) config file".

3. To check thermometer setup and calibrations of *beta*NQR,

6.4 Switching between pulsed and continuous wave (CW) RF

[1]Switching between a pulsed RF mode (2e, for example) and a mode using continuous-wave (CW) RF mode (1f, for example) requires certain changes to be made to the PSM on the DAQ webpage (isdaq01.triumf.ca:8081/?exp=bnmr), as well as on the platform itself. When working with pulsed RF, the first thing to do is go to the PSM page and **1**. set "All profiles enabled" to "y" for yes,

2. set each

of the enable profiles 1f, 3f, 5f, and fREF all to "n" for no,

3. set enable quadrature mode to "y",

4. set the "scale factor" to is maximum value of 255. It should look like Fig. 6.1-a on the webpage. Then pulse type and bandwidth can be selected on the "IQ modulation" (see Fig. 6.1-b).

5. Once these have been values have been set, you must remove the attenuation (ie:

[1]Written by T. Keeler

have all switches on the attenuation box; in Fig. 4.1-b, set to "off") that is located on the platform. This small box is located near the bottom of the RF rack, which is the very first rack on the left when opening the platform cage (see picture). When going from pulsed to CW, the PSM should be changed that only "1f profile enable" is set to yes, and quadrature and "all profiles" disabled (ie: set to no). Also the attenuation (approx. 10 dB) should be applied using the attenuation box pictured.

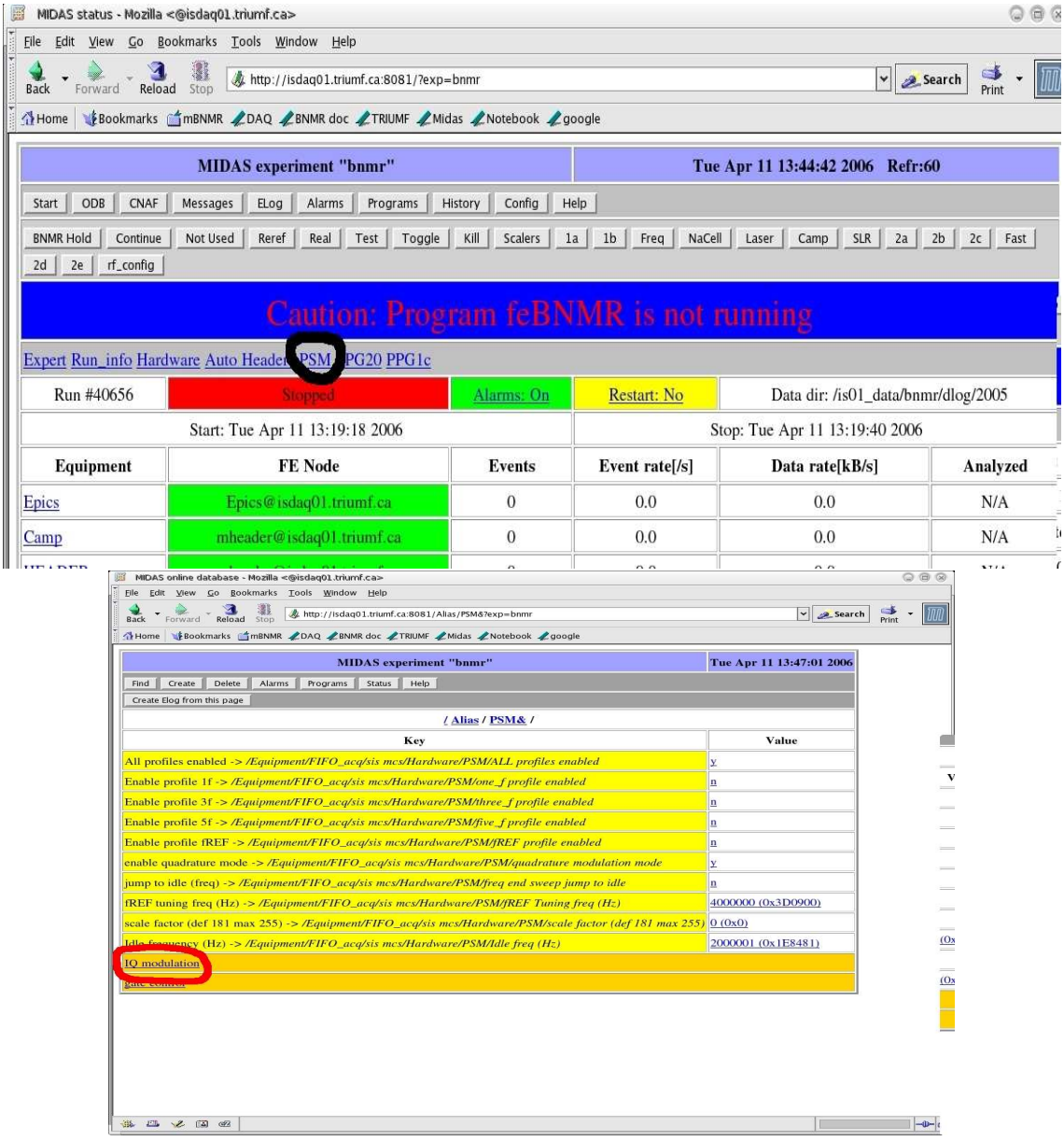


Figure 6.1: (a) DAC window, (b) PSM window.

Chapter 7

BNMR-RELATED CODES

7.1 TRIM simulation

[1]To run the TRIM simulation, ssh to *bnmr@bnmr1*, and create a new directory for your output results with command *mkdir*, and cd to the new directory. Typing *TrimSP* command will bring up a GUI to run the TRIM code. There are few things to provide before running the simulation:

-**Number of particles**: is the number of iterations in the simulation, and as high as the number is as accurate the simulation is. Generally starting with 10^4 to get a feeling of implantation fractions, and any number 10^5-10^6 is supposed to be enough.

-**Implant in**: is the structure of the sample. For example we write:

Y:0.077:Ba=0.154:Cu=0.231:O=0.538:Rho=6.54,Sr=0.2:Ti=0.2:O=0.6:Rho=5.12, for stopping Li in $YBa_2Cu_3O_7/SrTiO_3$. These are the chemical symbols of each atom (ex. Y for yttrium), followed by its fraction from the total number of atoms in a unit cell (f[Y]=$\frac{1}{1+2+3+7}$=0.077) and the density of the layer density Rho (6.54 g/cm^3 for $YBa_2Cu_3O_7$). Comas, colons, and equal signs must be used as in the example above.

[1]Written by H. Saadaoui

-dmax: thickness of each layer separated by commas (in Å).

-dmin: minimum thickness of the layer, if you leave it empty then it assumed that dmin=dmax, and applies for only single layered structures.

-dstep: steps in thickness at which the simulation is performed, and applies for only single layered structures.

-dincr: is the increment in depth at which the number of Li stopping is calculated. The TRIM code calculates the number of stopping Li at 100 depth points, so 100× dincr should be larger than the maximum implantation depth.

-E max: full energy of Li ions in eV.

-E min: minimum energy of Li ions in eV.

-E step: steps of energy increments in eV.

It is always good to run a test with low number of particles, before using a fairly high number. Once the simulation ends, sub-directories corresponding to different energies and thicknesses will be created (example: "d=400e=16000/" for a a first layer of 400A and energy 16 keV.). cd to each of the sub-directories and the data of fraction of Li versus depth can be found in files with .rge prefix. Other files contain information about the run. See the Gui interface in Fig. 7.1-a for an example, and the graph generated in Fig. 7.1-b.

There is another graphical interface for TRIM which is SRIM. To access the SRIM code, login to tnt2k accounts, and open *SRIM2003* icon on Desktop. This will bring an awfull colored graphical interface. However, the results of both TRIM and SRIM simuations are supposed to be the same.

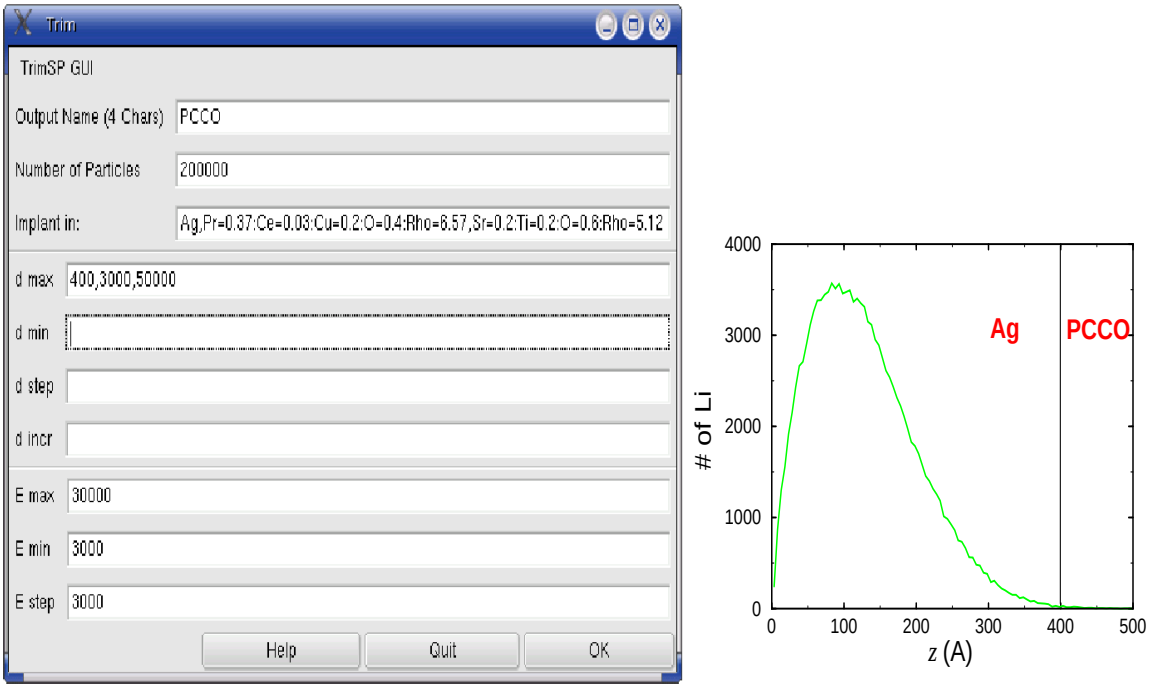


Figure 7.1: (a) A GUI interface used to generate the figure on the right for simulating the stopping distribution of 2.10^5 $^8Li^+$ ions in $Ag/Pr_{1.85}Ce_{0.15}CuO_2/\ SrTiO_2$, with thicknesses of 400/3000/5000 Å, respectively. The density of PCCO is 6.57 g/cm^3, and of $SrTiO_2$ is 5.12 g/cm^3 (Note that we don't supply density of Ag as the code includes densities of all elements). (b) Graph generated by running the TRIM simulation using the values shown in the GUI interface in Fig. 7.1.

7.2 BNMRFIT code

7.3 BNMRMINUITFIT code

7.4 Field distribution code

Bibliography

[1] Written by Zaher Salman, see http://bnmr.triumf.ca/.

[2] Written by Terry Parolin

[3] Written by Hassan Saadaoui

[4] Written by Dong Wong

[5] Written by Rob Kiefl

[6] Written by Todd Keeler

[7] Written by Hussein Masrur

[8] Written by Phil