IBeAM

Ion Beam Analysis of Materials Facility

User Manual

2013

Barry Wilkens, Mike Johnson, Derek Abeyta, Mark Mangus Jr

Safety Precautions

Radiation

Extensive efforts have been made to reduce the radiation produced by the Tandetron to far below accepted non-occupational levels. However, under fault conditions or with beams other than those for which a specific maximum radiation level has been guaranteed, it is possible to produce potentially hazardous ionizing radiation. It is the responsibility of the operator of this instrument to have available at all times an operating and calibrated radiation detector sensitive to X-rays or gamma rays from 20 keV to several MeV. If ions other than those for which a specific radiation level has been guaranteed, are used in the Tandetron analyzer, nuclear reactions may occur which will produce neutrons or other forms of ionizing radiation under normal operating conditions. It is the responsibility of the user to attend a radiation safety seminar provided through the Office of Radiation Protection at Arizona State University, and wear a radiation film badge issued through that office at all time while in the accelerator facility. For radiation safety seminar times and scheduling, please call (480) 965-6140.

High Voltage

Electrical circuitry in the Tandetron is designed to shield and interlock against exposure of personnel to dangerous voltages. There are however, **LETHAL** voltages present in various parts of the Tandetron Analyzer which make it essential for the user to stay within designated areas and use caution when operating the equipment. Do not touch any equipment you have not been trained and authorized to use. The obvious area of High Voltage is in the source area. Never poke anything through the cage. Never put anything over the cage and never try to bypass the cage interlock system. A less obvious high voltage hazard is the electrical connections on the ionization gauges, which measure the vacuum inside the beam line. Always use caution when handling the ionization gauges.

Gas

The sulfur hexafluoride insulating gas sealed within the high pressure tank is colorless, odorless, and heavier than air. While it is non-toxic, it will not support respiration. Adequate ventilation has been provided but in the event of a system failure, exit the building and call the emergency number.

Interlocks have been provided to reduce the probability of an accident. An attempt to defeat the interlocks puts the user in personal danger.

Contact Information

IBeAM

Name	Office	Office Phone	Home Phone	Cell Phone
Barry Wilkens	GWB66	(480) 965-9613	661-9874	(480)285-9054
Robert Culbertson	PSF232	(480) 965-0945	968-5992	
Nicole Herbots	PSF234	(480) 965-0581	968-5992	

Center for Solid State Science

Name	Office Location	Office Phone
Main Office	PSA213	(480) 965-4544
Adrienne Fuentes	PSA213	(480) 965-4546

Safety and Hazardous Waste

Name	Office Phone
Environmental Health & Safety (Hazardous Materials/Asbestos Incidents)	(480) 965-1823
Hazardous Waste Removal Info: http://sols.asu.edu/safety/pdf/ASU_Hazardous_Chemical_Fact_Sheet.pdf	(480) 965-3899
Police, Fire, Medical (Do not dial 8)	911
Facilities Management	(480) 965-3633
ASU Police	(480) 965-3456

IBeAM

Ion Beam Analysis of Materials Facility
LeRoy Eyring Center for Solid State Science
Arizona State University
Tempe, Arizona

User Manual Contents

This Page Intentionally Left Blank

Section I

Emergency Procedures

Power Failure
(Accidental System Vent)

Flooding/Fire

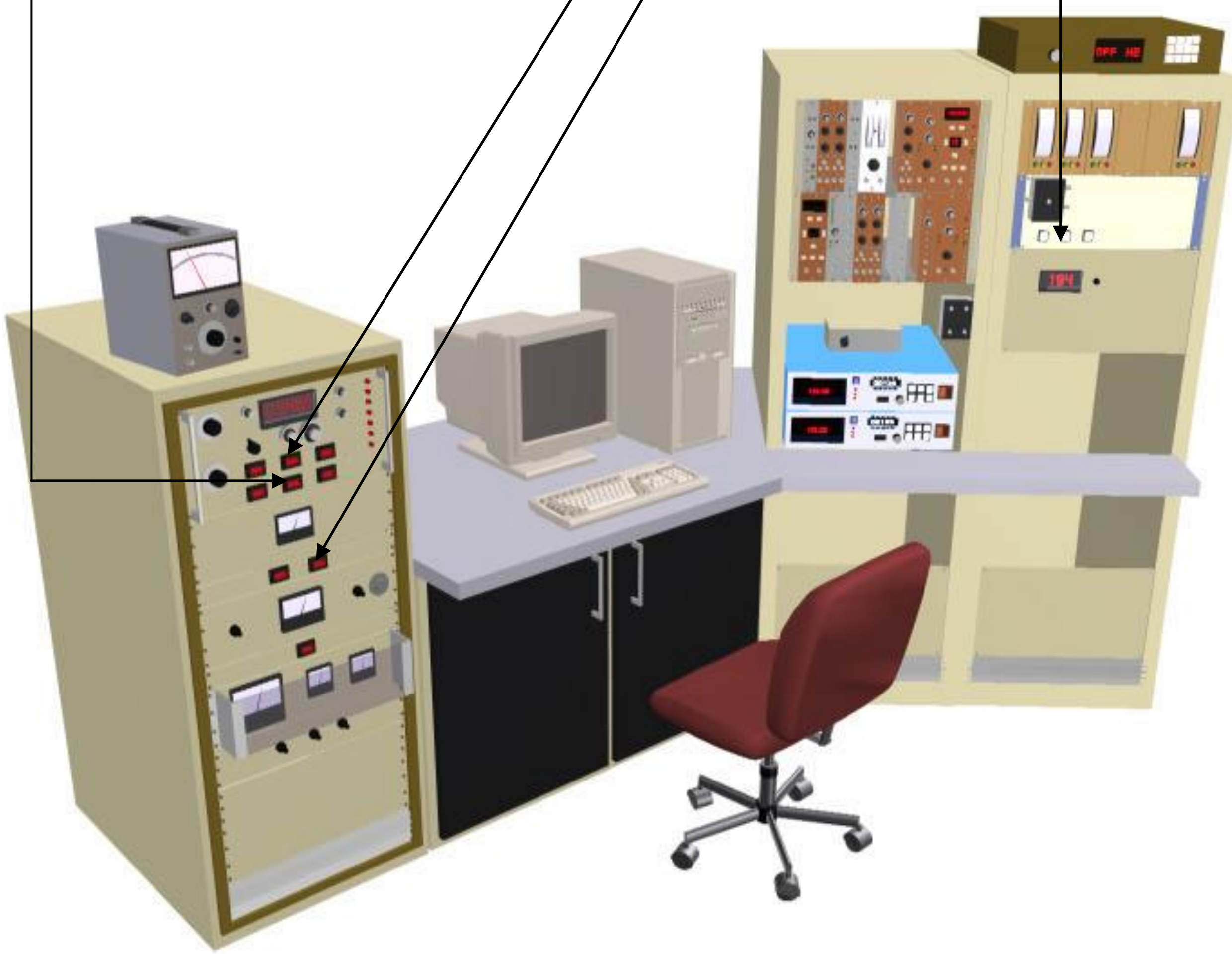
Loss of Sample in Vacuum Chamber

This Page Intentionally Left Blank

Power Failure (Accidental System Vent)

If electrical power to the accelerator should fail or dip, you will hear a lot of hissing and clanking. This is the sound of all the safety valves on the turbo pumps closing down the gate valves. Act quickly but calmly.

1) **Turn Detector Bias to 10 Volts**
2) **Close RBS gate valve**
3) **Close Isolation Gate Valve**
4) **Push “Accelerator” Button OFF (Out is OFF)**
5) **Push “Injector” Power Button off**



> **Warning!** **If you weren’t able to perform the above steps within 3-5 minutes of power failure, stop at step 5 and call Barry or Bob. If enough time has elapsed, the three main turbos will have wound down. Quickly opening the gate valves with the accelerator still under vacuum will cause back streaming of oil into the vacuum system or possibly worse. Another scenario would be that the turbos could be spinning when you open the gate valves to a vented accelerator at atmosphere. This would flex the turbo’s rotor into its stators and destroy the pump. Each turbo pump is approximately $12,000.00! Be careful!**

Continue to next page...

6) Push "Vacuum Bypass" on (in), you will hear clanking as the gate valves open.

7) If there are one or more interlock lights on, you will have to allow vacuum to recover before high voltage and sources can be turned on (The Turbo pumps may have to be restarted). This is a good time to contact Barry or Bob if you haven't done so already.

8) Leave a note on the operator's console explaining what has happened. Do not try to restart the source or turn up the High Voltage.

9) If the power failure was more than a "glitch", the computer will reboot, causing you to lose any un-saved files.

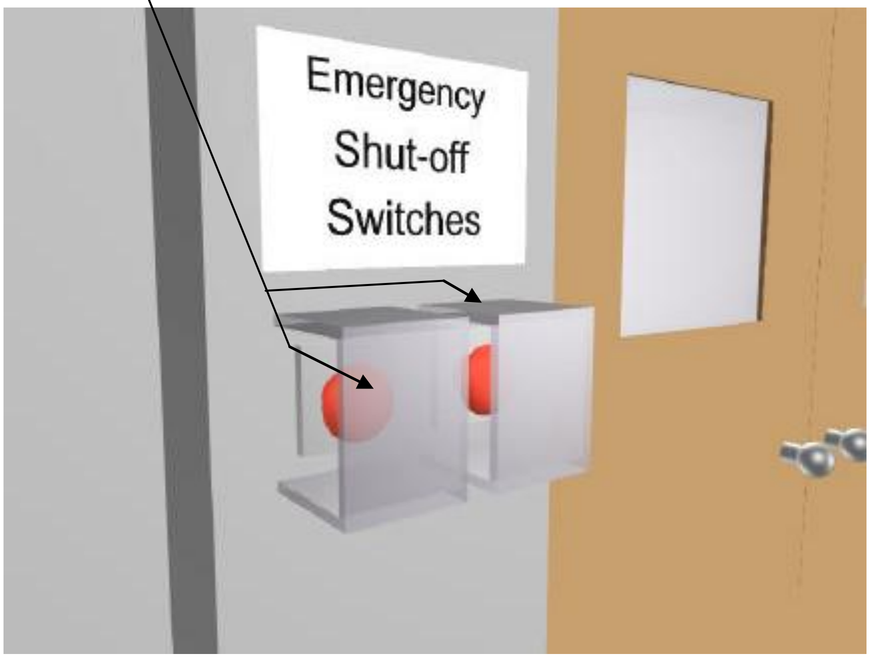
Phone Numbers:

	Office:	Home:	Cell:
Barry Wilkens	(480) 965-9613	661-9874	(480) 285-9054
Dr. Robert Culbertson	(480) 965-0945	968-5992	

Flooding/ Fire

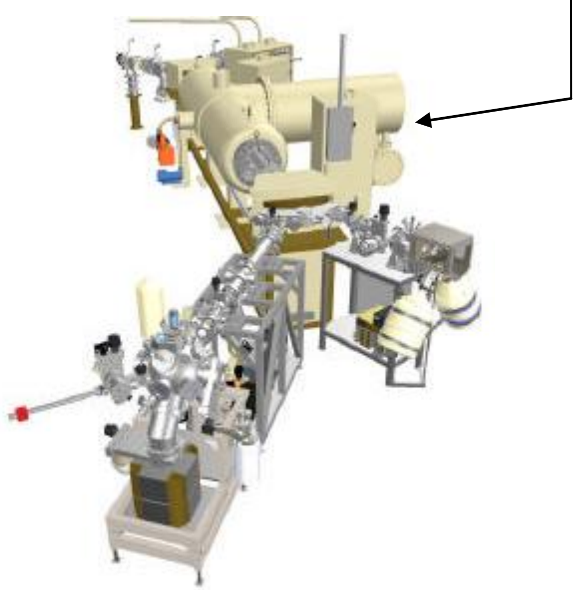
AUTHORIZED PERSONNEL ONLY

1) **Push <u>both</u> emergency power cut-off buttons located on the wall by the North entrance to the lab.**



AUTHORIZED PERSONNEL ONLY

2) **Pull the accelerator shut off lever to shut off power to the accelerator.**



3) Call 911 to report the incident.

4) Exit the Building.

Loss of Sample inside the Vacuum Chamber

If you drop your sample inside the analysis chamber, call Barry to retrieve the sample. Use another sample holder in the mean time to continue with your analysis. Do not try to retrieve a sample without Barry present. If the analysis chamber is vented, the Ion pump must be restarted; a rather tricky and time consuming operation.

Name	Office Location	Office Phone
Barry Wilkens	**GWCB66**	**(480) 965-9613**

Section II

Facility Overview

Operational Summary

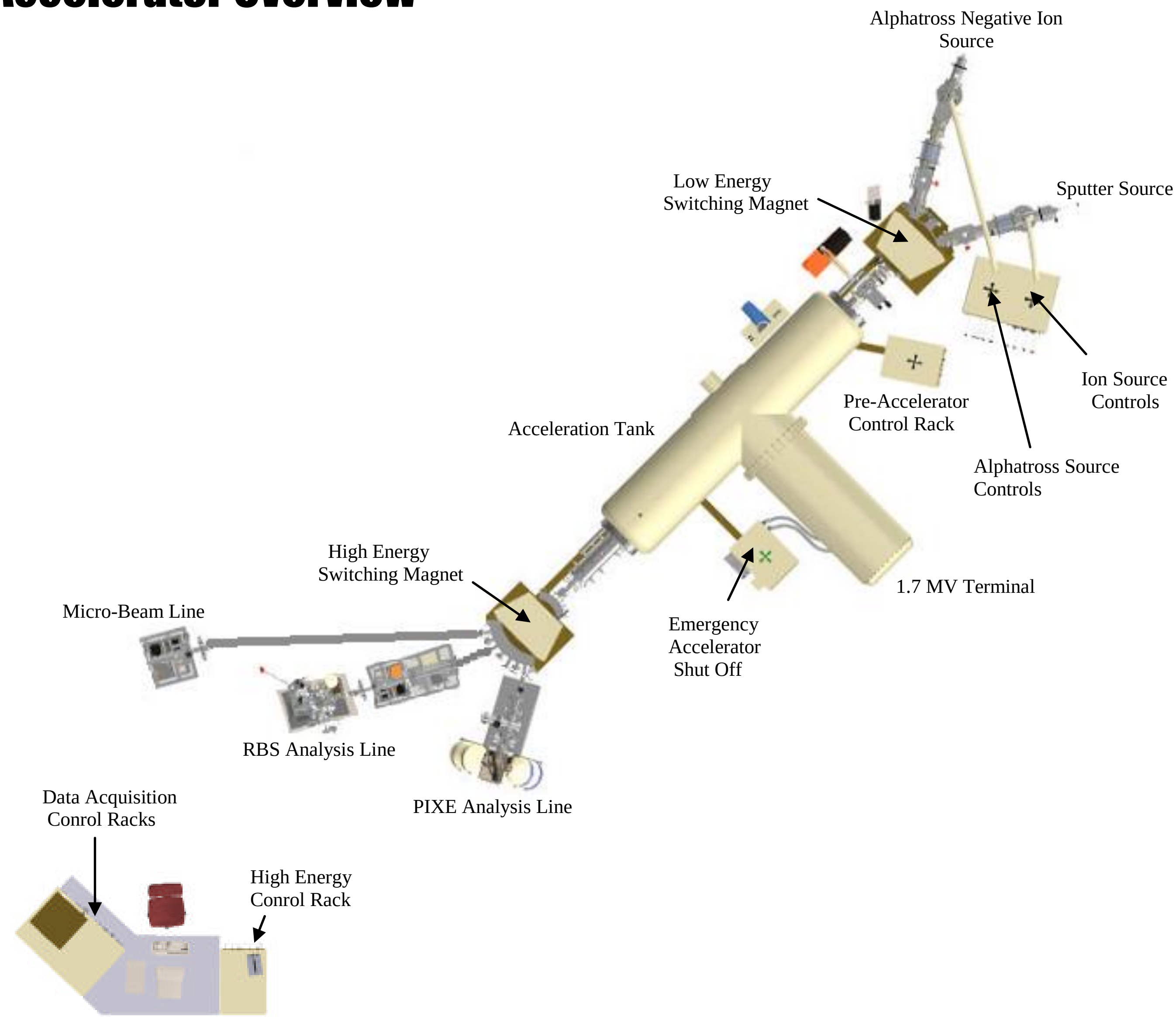
Accelerator Overview

This Page Intentionally Left Blank

Operational Summary

The lab consists of a 1.7 million volt tandem electrostatic accelerator with three beamlines and sample analysis end stations. Everything is done in vacuum with the exception of the External PIXE line. Typically accelerators are used for studies in nuclear physics, however since the mid 70's they have increasingly come to be used for chemical analysis of materials using a variety of techniques and physical processes. A major reason for this development was the introduction of solid state detectors in the late 60's and early 70's. This facility was installed on the ASU campus in the fall of 1992 having been moved from an industrial research lab in New Jersey. The lab is used primarily for compositional and structural analysis of thin films and surfaces of materials associated with and developed for electronic applications ranging from conducting, semiconducting and insulating layers, to coatings and even magnetic materials used in solid state memory devices. The actual physical processes by which this is accomplished involves directing a beam of two to three million volt helium ions at the sample for analysis and measuring the ions scattered back from the sample. Though at least 75% of the work is done in these areas, there is a wide range of projects using the IBeAM facility ranging from archaeology (chemical analysis of objects of antiquity) to geology (rocks, minerals, meteorites, etc.) to environmental studies (air and water pollution chemical component analysis) to objects of art (paint pigment analysis). The working mode for this lab is to train students who are doing research to operate the equipment and understand the basic principles of the various analysis techniques. The experience of using state of the art materials analysis apparatus is extremely valuable, especially to those who will be seeking employment in the semiconductor field. We have and have had a number of undergraduate students assisting in the maintenance and operation of the facility. Several courses use our lab as part of the curriculum. Another use of the facility includes giving group tours ranging from grammar school up through high school and college recruiting. The IBeAM lab serves an important role in not only bringing together a wide variety of disciplines in the various types of research, but also provides a state of the art environment for students at both the undergraduate and graduate level to gain "hands-on" experience in materials research and analysis.

Accelerator Overview



Note: Area designations will be referred to throughout the Manual. Users should familiarize themselves with these designations.

Excellent References for Further Reading on Ion Beam Analysis

Authors	Title	ISBN Number
Wei-Kan Chu James W. Mayer Marc-A. Nicolet	*Backscattering Spectrometry*	0-12-173850-7
S.A.E. Johansson J.L. Campbell	*PIXE a Novel Technique for Elemental Analysis*	0-471-92011-8
Leonard C. Feldman James W. Mayer S. Thomas Picraux	*Materials Analysis By Ion Channeling (Submicron Crystallography)*	0-12-252680-5
Leonard C. Feldman James W. Mayer	*Fundamentals of Surface and Thin Film Analysis*	0-444-00989-2
James W. Mayer Eriksson Davies	*Ion Implantation*	Academic Press 1970
James W. Mayer E. Rimini	*Ion Beam Handbook for Material Analysis*	0-12-480860-3
Tesmer Nastasi Barbour Maggiore Mayer	*Handbook of Modern Ion Beam Materials Analysis*	1-55899-254-5

This Page Intentionally Left Blank

Section III

User Level I

Do Not attempt to perform any of the procedures described in the following sections without having been first “checked out” by Barry Wilkens or another qualified user.

Sample Loading

Data Acquisition

Sample Unloading

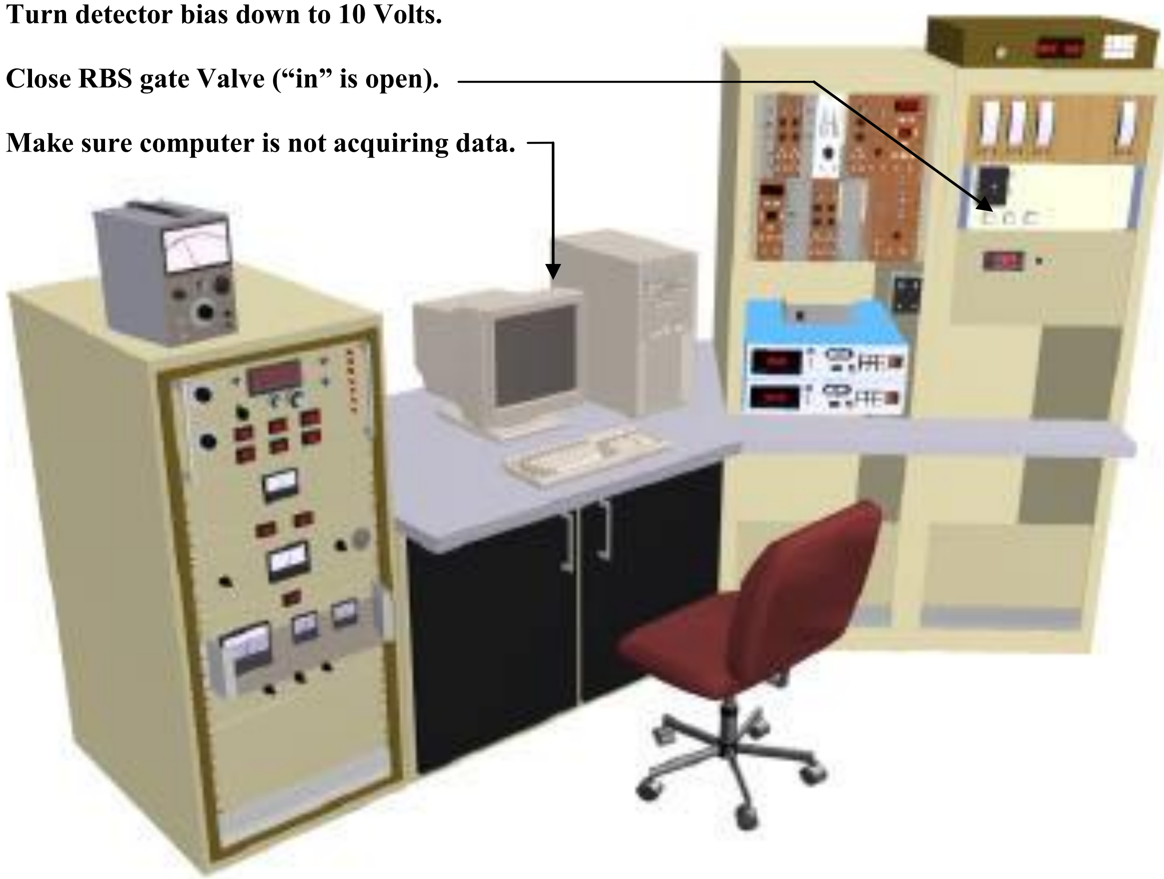
This Page Intentionally Left Blank

Sample Loading

1) Turn detector bias down to 10 Volts.

2) Close RBS gate Valve ("in" is open).

3) Make sure computer is not acquiring data.



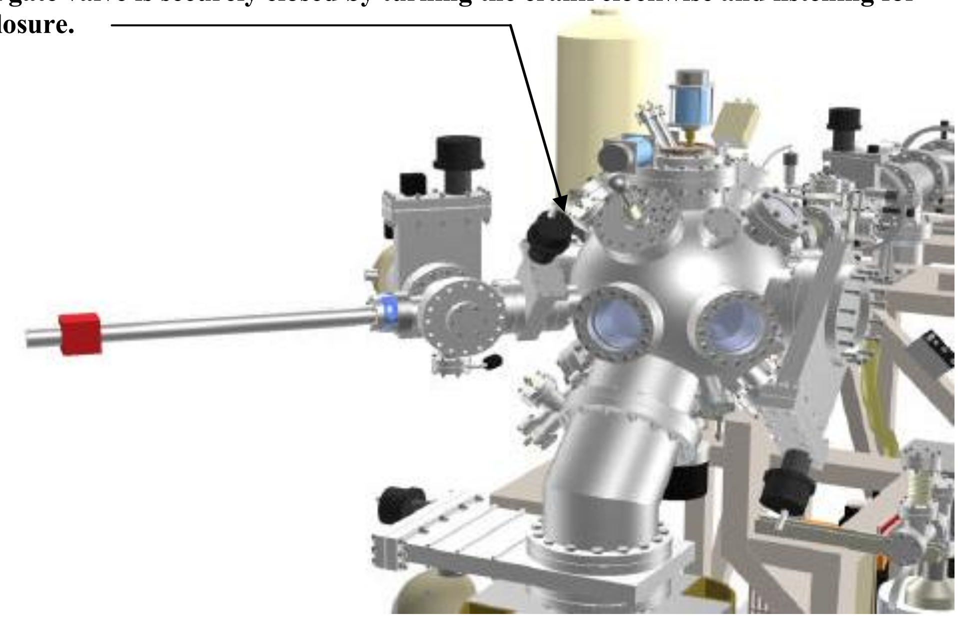
4) The sample needs to be mounted on either the copper or carbon backed sample holder. Samples should be mounted at the sample hood while wearing gloves. Do not touch any parts that are to go inside the analysis chamber with your bare hands. This will contaminate the chamber.

5) Use tweezers to lift the sample clip. Slide sample underneath.

6) If necessary, loosen the screw holding the clip. Be careful with the carbon backed sample holder; it is brittle.

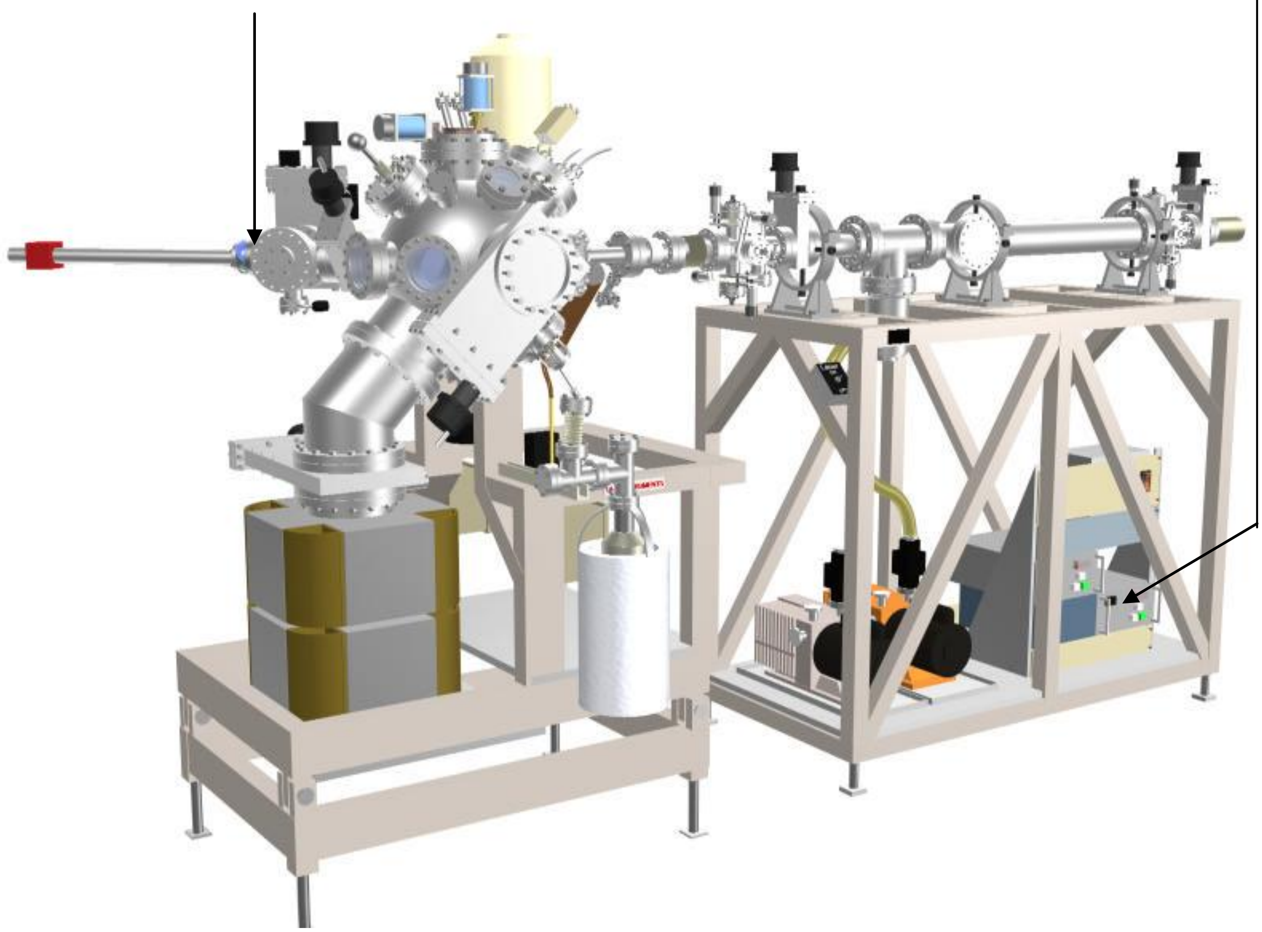
7) When sample is mounted, tap the sample holder on the counter to make sure the sample is secure and will not drop inside the chamber.

8) Check that the load lock gate valve is securely closed by turning the crank clockwise and listening for the "clank" indicating closure.



9) Turn off the load lock turbo pump, ("pumping unit" button) and <u>wait for venting</u>.

10) Remove load lock cover using gloves. Lock sample on actuator arm.



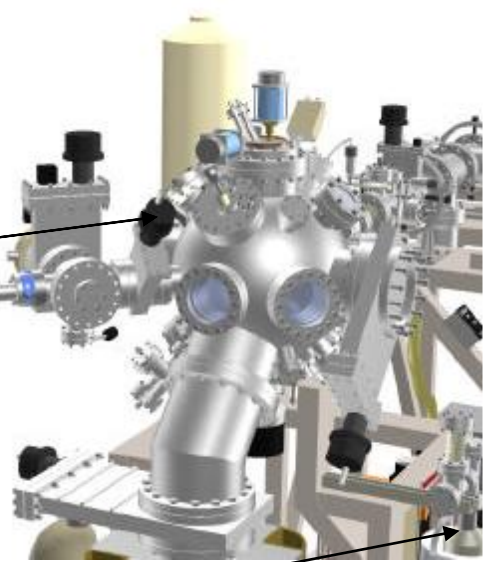
11) Replace load lock cover

12) Turn on load lock turbo pump.

13) Press on the load lock cover until the vacuum seals.

14) Watch the overhead Convectron gauge until the pressure reading “bottoms out” (approx 1 mT).

15) Wait an additional 10 seconds.



16) Open load lock gate valve completely by turning crank counter clockwise.

17) Use magnet to load sample ~~into~~ goniometer.

18) With the sample holder securely in the goniometer, use magnet to retract actuator arm back into the load lock chamber

19) Close the load lock gate valve by cranking clockwise.

20) Check to see if motor control module is on (2 green LED’s will be lit).

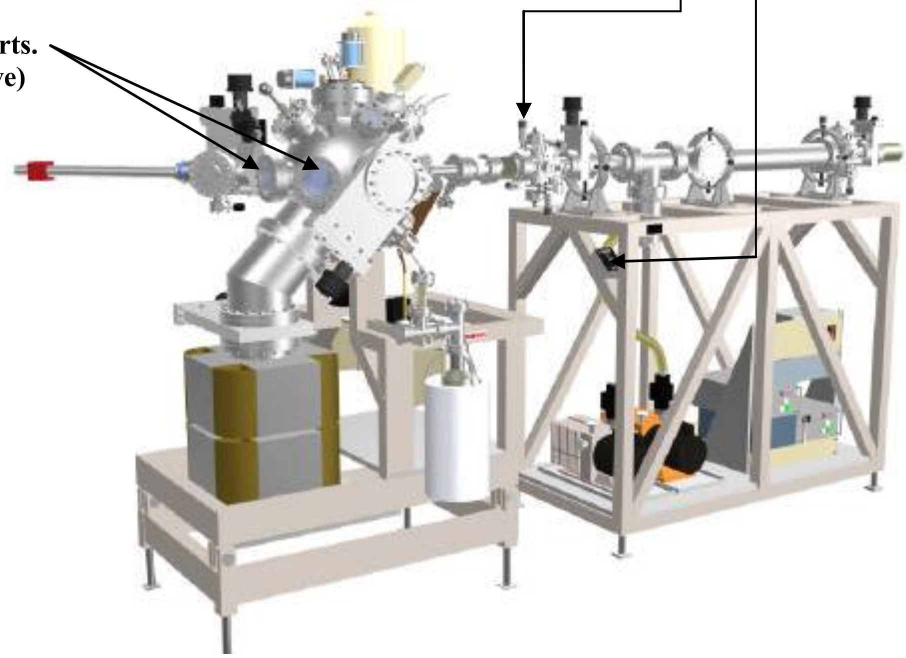
21) Rotate the sample to analysis position using “Motor Control” program by indexing the θ stepper motor to desired position. (0˚ is the load-lock position and 90˚ is facing beam).

22) Use the laser to make sure the beam is hitting the target.

23) Adjust collimator slits if necessary.
(Note: for correct Energy Calibration, slits should be centered on “0” position.)

24) Turn laser off.

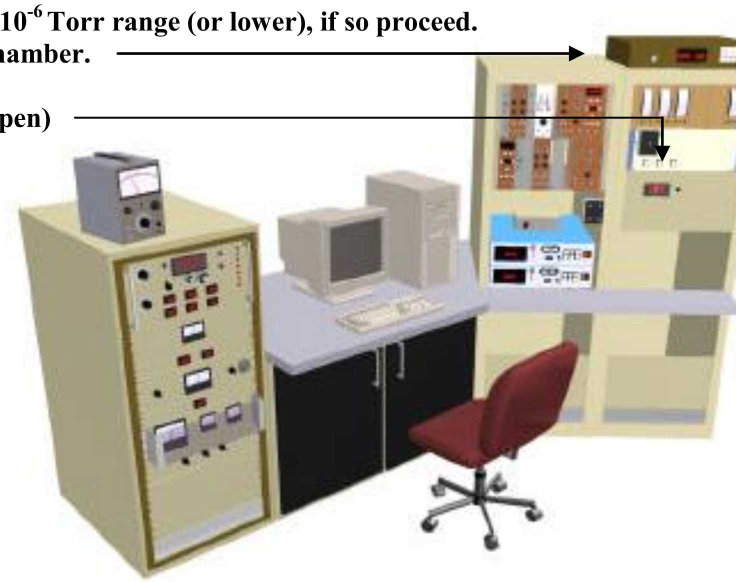
25) Cover all chamber view ports.
(Detectors are light sensitive)



26) Slowly increase the detector bias to required voltage.

27) Check that chamber pressure is in 10^{-6} Torr range (or lower), if so proceed.
If not, call Barry, you vented the chamber.

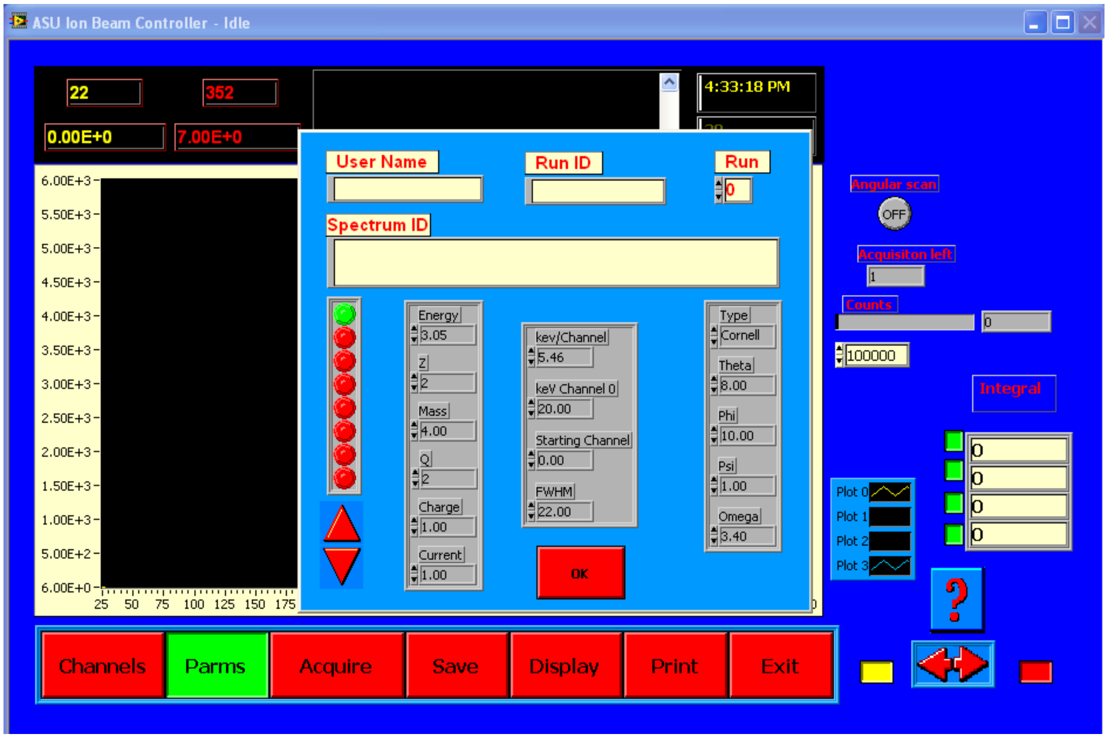
28) Open the RBS gate valve. (“in” = open)



****The Sample Loading Procedure is now complete.**

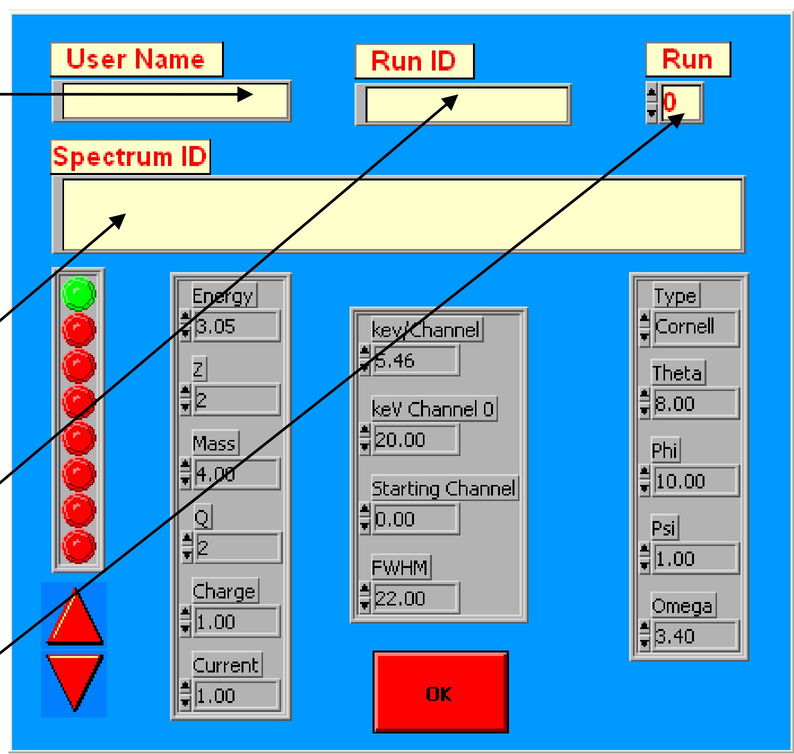
Data Acquisition

1) In the Windows screen, double click on the “IBeAM Control” icon. The following screens will appear.

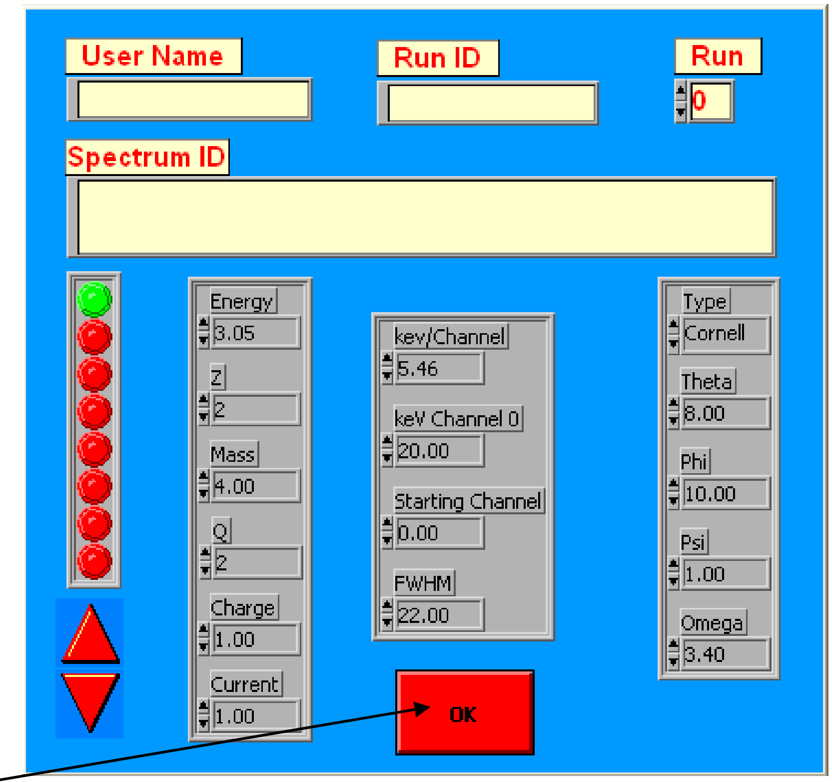


2) Enter the following information:

- Enter the directory on the y: drive you want the data files save in. (for example, entering “Wilkens” will save the files in the Wilkens folder on the y: drive, but “Wilkens\2012.10.09” will save in the 2012.10.09 sub-folder of the Wilkens folder on the y:)
- Information on the type of sample you are analyzing. This is appended to the header in your file(s).
- Run I.D. is what you want the file(s) to be named. Most people use the current date, or the sample name and current date.
- Run number adds the current run number to the end of the Run I.D. It automatically increments.



3) Check that the following parameters are correct for your analysis.

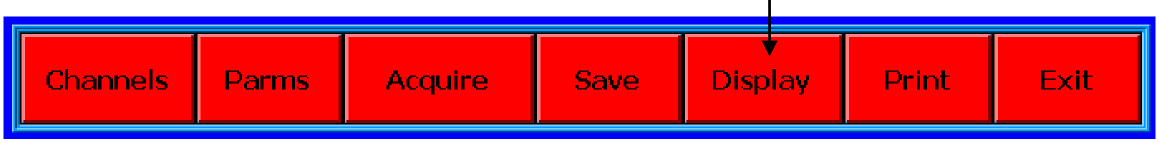


- Energy of incident particle.
- Z value for incident particle. (He Z = 2)
- Mass of incident particle. (He mass = 4)
- Charge of incident particle. (He++ = 2)
- Make sure green light is indicating
- that ADC1 (top) is being used for acquisition.
- kev/Channel is set to approximately 5.4.
- keV Channel 0 (Offset) is set to
- approximately 20 - 40.
- Starting Channel set to 0.
- FWHM (detector resolution) is set to 20.00.
- •Type set to "Cornell"
- •Theta set to desired sample angle
- •Phi set to 9.0
- •Psi set to 0.0
- •Omega set to 3.4

4) Press OK.

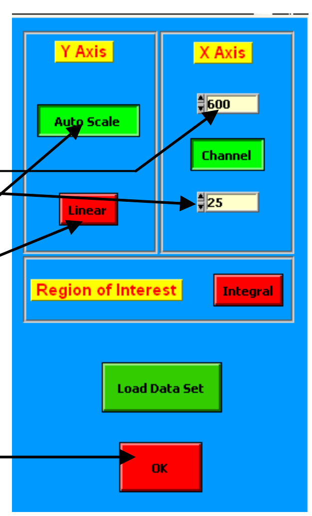
***Note: if the particle parameter column doesn't show up, you could be in "PIXE" mode. Check the "channels" button to make sure you are in "RBS" mode.**

5) Press Display button to customize your acquisition screen.



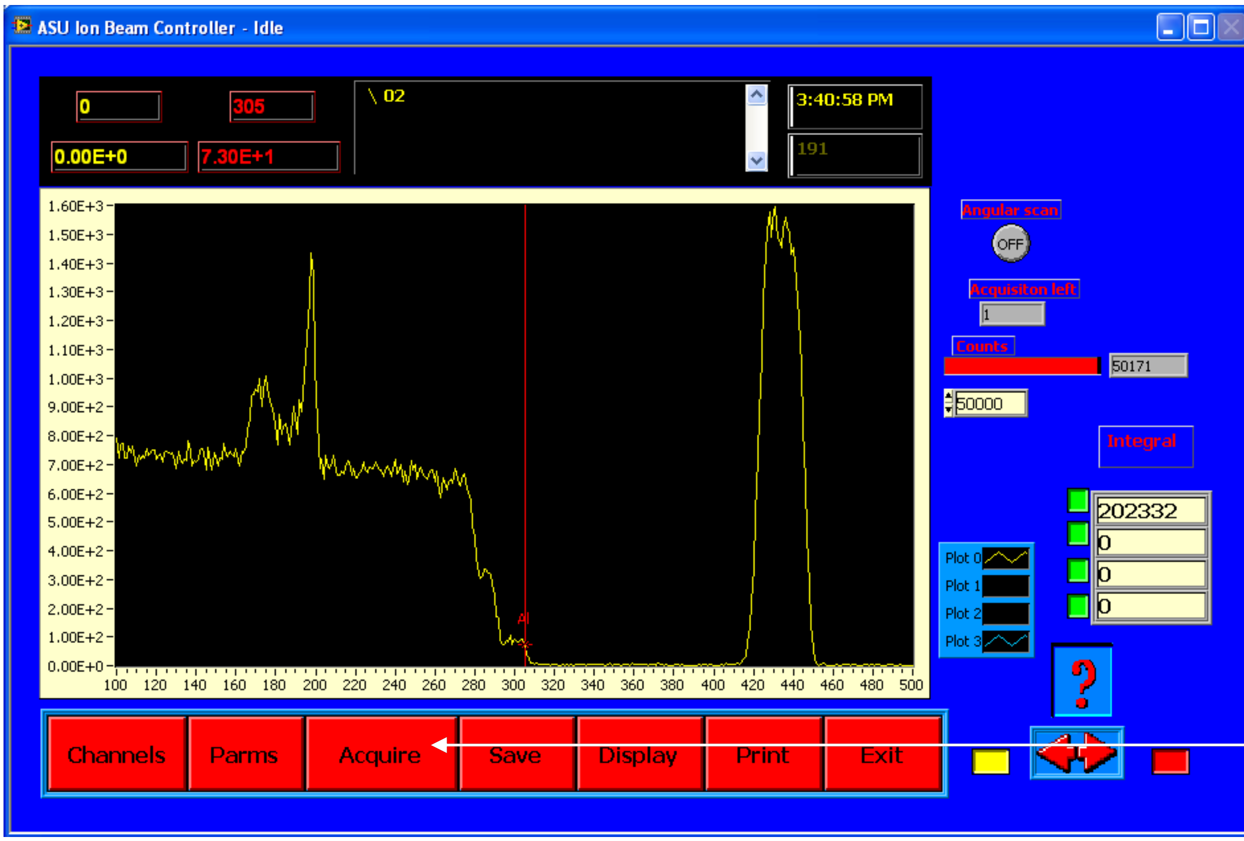
6) On the following Display screen, customize the following parameters:

- **X-axis limit.**
- **X-axis origin.**
- **Y-axis limit.**
- **Y-axis scaling**



7) Press OK.

8) Set preset to desired value. Now you are set to acquire data. Press the Acquire button. This both clears the screen and places the software in "Acquire" mode.

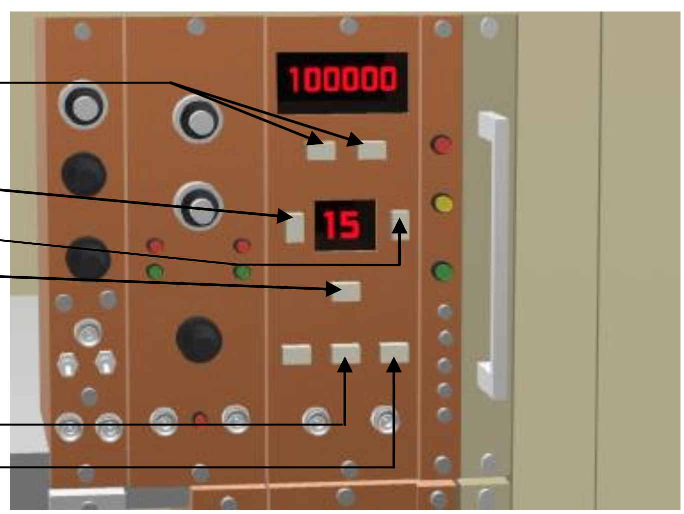


9) Check High Energy Control Rack if F-cup toggle switch is set for Manual or Automatic Mode. Set switch to Auto mode to have F-cup controlled by the program once the Acquire button has been pressed.

10) Check Parameters on the timer counter:

- Display mode is in "Gate" and "Timer".
- Coefficient set to max value (9).
- Exponent is set to max value (7).
- Time Base is set to "External".
- If counter has reached max counts, 9E7, the counter will NOT count. To start it counting again:

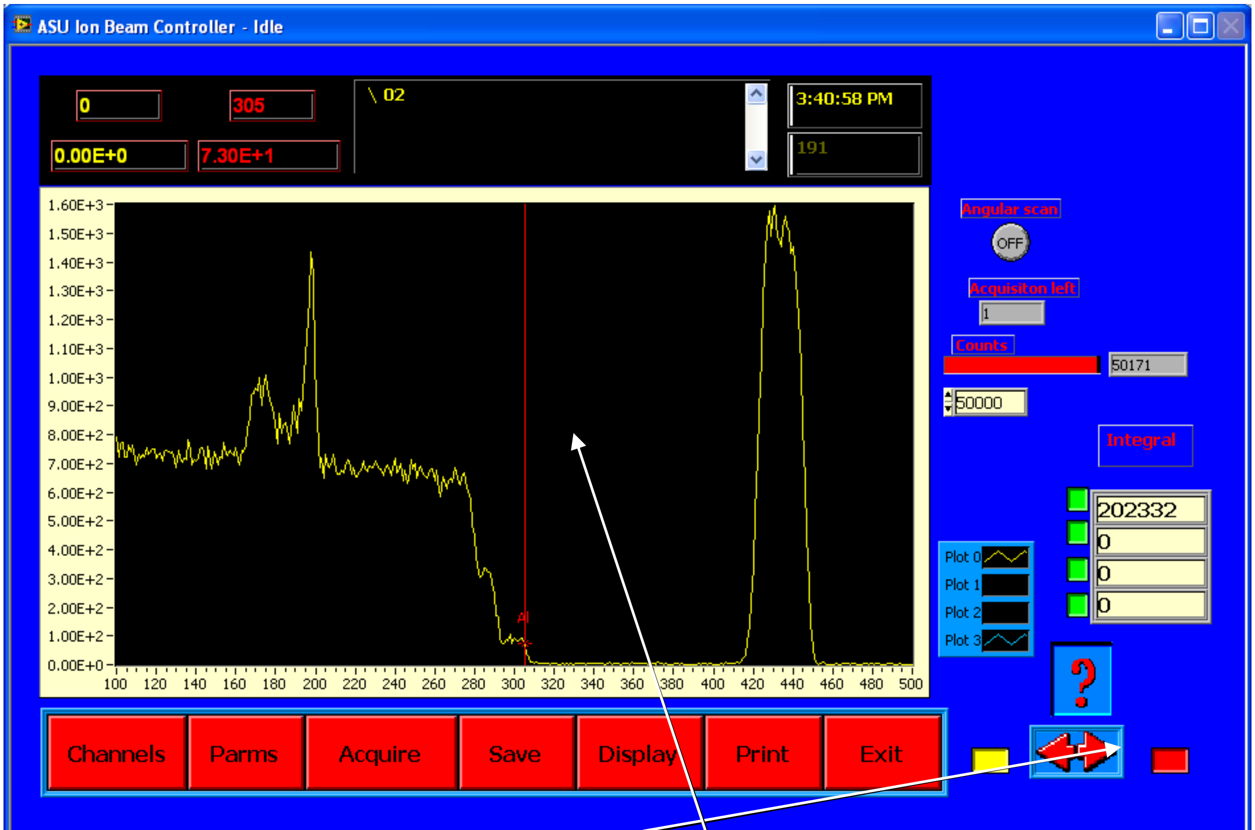
  1) Press Reset
  2) then Press Count



Continue to next page for File Saving and Conversion

File Saving and Conversion

1) **When data has been acquired, press the "save" button. Note the spectrum label will turn from red lettering to yellow lettering when the file has been saved.**



2) **You can use the arrow indicators to move the identification cursor to identify peaks in your spectrum.**
(The "?" button must be depressed for this option.)

3) **RBS**
Your file has been saved with an *.RBS extension. This type of file is compatible with the RUMP analysis software. If you plan to analyze your data in any other software, you will want to save your data as an ASCII file. You have this option under "SAVE" as well. Your files will be saved on the default drive (Y:) unless you select otherwise.

PIXE
When using the PIXE configuration your files will be saved as .spm files which are compatible with GUPIX analysis software.

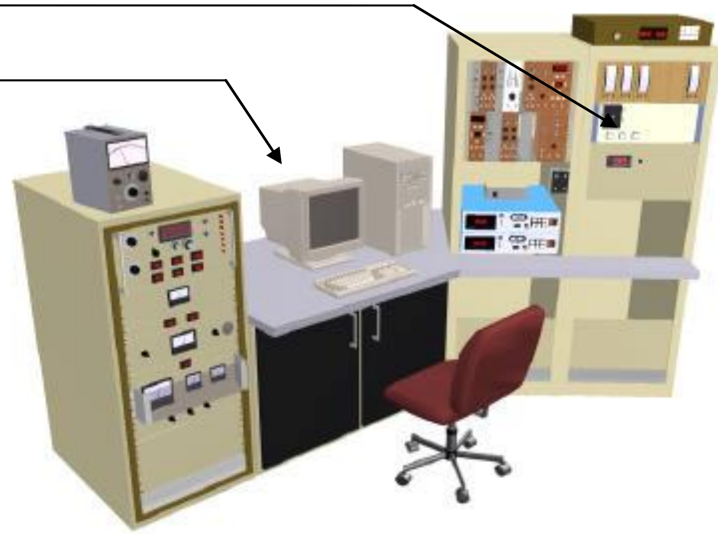
File Saving and Conversion Procedure is Complete.

Sample Unloading

1) Turn detector bias down to 10 Volts.

2) Close RBS gate Valve.

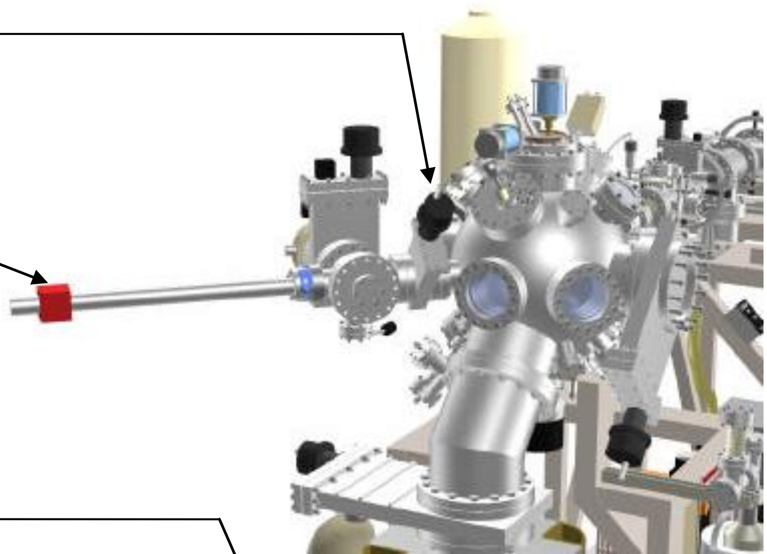
3) Make sure the computer is not acquiring data.



4) Rotate the sample to the load-unload position by pressing "GoTo" under "Unload Sample Position" on the Motor Control Program Interface. Theta should be set to 0º for the unload position.

****** Before Beginning Step 5 ******

Make sure the load lock turbo pump is on and the chamber is completely pumped down.



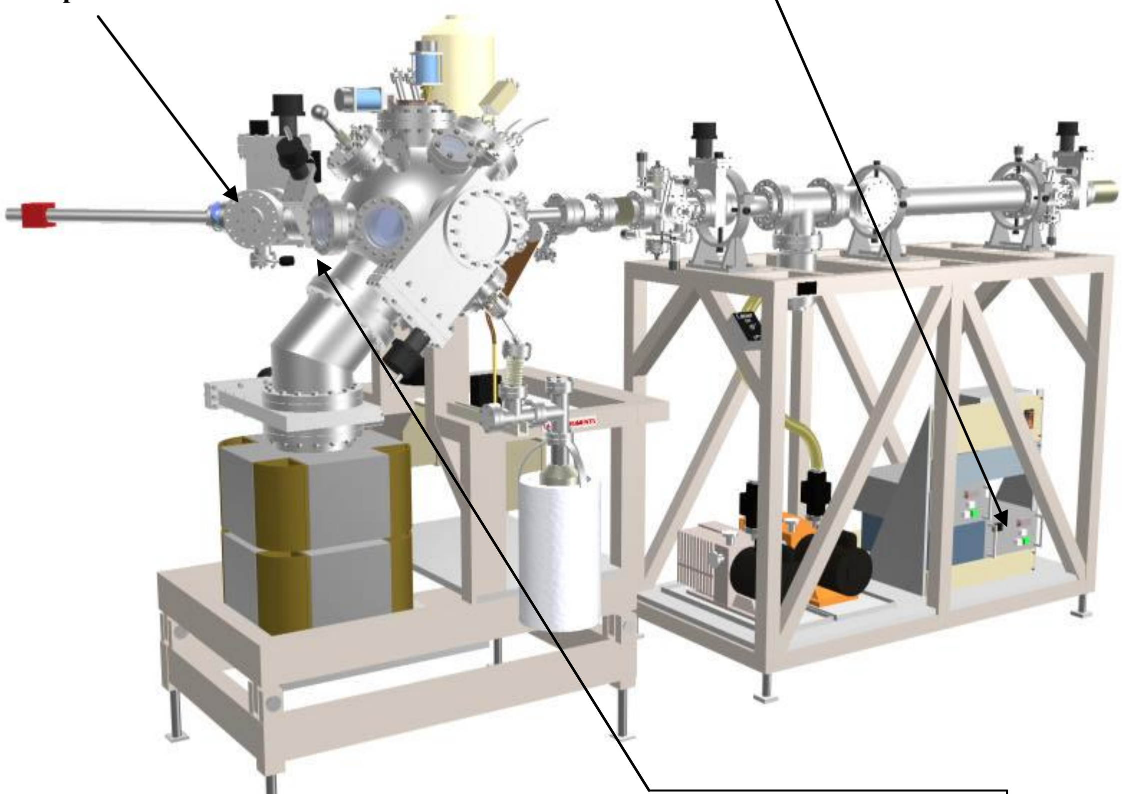
5) Open load lock gate valve completely by turning the crank counter clockwise. (Load lock turbo pump should still be on at this time)

6) Use magnet to retrieve the sample from goniometer.

7) With the sample holder securely locked on the actuator arm, retract the actuator arm back into the load lock chamber

8) Close the load lock gate valve securely by turning the crank clockwise.

9) Turn off the load lock turbo pump, and wait for the chamber to come to atmosphere.



10) Remove load lock cover using gloves, and retrieve the sample from actuator arm.

11) Replace the load lock cover

If you are finished with your analysis and have no other samples to load:

12) **Turn on load lock turbo pump after replacing cover on load lock chamber.**

13) **Press on the load lock cover until the vacuum seals.**

14) **Make sure that vacuum is obtained in the load lock chamber. Watch the overhead Convectron gauge until the pressure reading "bottoms out" (approx 1 mT).**

If you need to load your next sample, repeat the steps in the Sample Loading section.

This Page Intentionally Left Blank

Section IV

User Level II

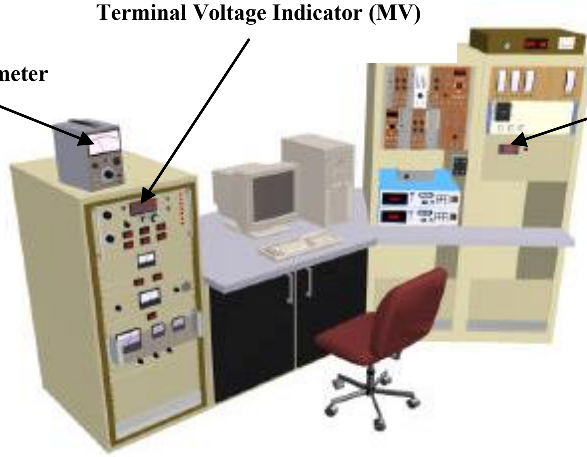
Adjusting Beam Energy

Tandetron Shut-down Procedure

This Page Intentionally Left Blank

Adjusting Beam Energy

This procedure assumes that there is already a beam on the target sample. It describes how to incrementally increase or decrease the terminal voltage and switching magnet's field to change the energy of the beam, and how to maximize the beam current. Typically a recent log sheet will have parameter settings for common terminal voltages used. Set all parameters to these values and locate beam maximum. If no logged values exist for energy desired than follow procedure below.



1) Calculate the desired terminal voltage for the energy level you require. The formula is as follows:

$$Terminal\ Voltage\ (MV) = \frac{Energy\ Level\ (MeV) - [Preaccelerator\ Voltage\ (MV) + Extractor\ Voltage\ (MV)]}{(1 + Ion\ Charge)}$$

> Example: You want a 2MeV beam of He^{++}, your preaccelerator voltage is 40 kV, and the extractor has 18 kV. The Terminal voltage setting is:
>
> $$Terminal\ Voltage\ (MV) = \frac{2(MeV) - [0.040(MV) + 0.018(MV)]}{(1 + 2)} = 0.647$$

2) Approximate the switching magnet setting you require using the current settings and the following formula:

$$\frac{\sqrt{Current\ Magnet\ Setting}}{Current\ Terminal\ Voltage} \approx \frac{\sqrt{Desired\ Magnet\ Setting}}{Desired\ Terminal\ Voltage}$$

> Example: You have found that the magnet setting for a .99 MV terminal voltage was 235. You want the magnet setting for your 2MeV terminal voltage calculation. The setting is:
>
> $$(0.647 \times \frac{\sqrt{235}}{0.99})^2 = 100$$

> **Note: Do not increase the terminal voltage above 1.43 MV. If terminal voltage is to be increased above 1.10 MV, do it slowly with periodic pauses to prevent the beam from arcing.**

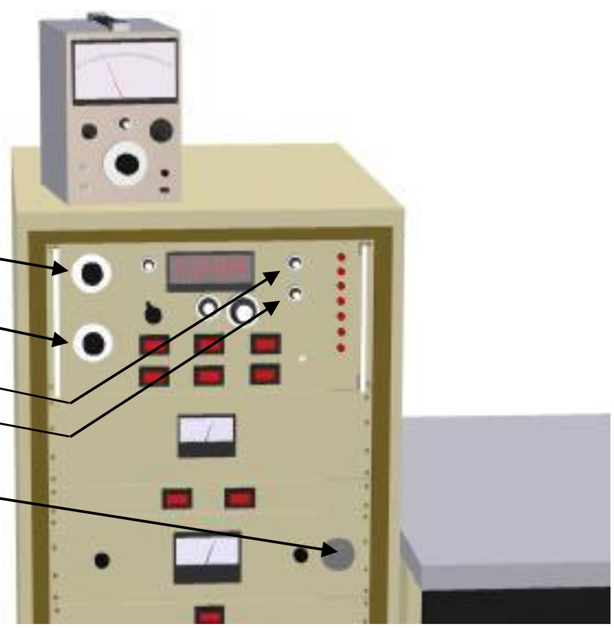
Continue to next page…

3) **Beginning at a terminal voltage setting where a maximum beam current has been obtained, slowly adjust the terminal voltage in 20kV increments towards the terminal voltage desired while adjusting the switching magnet as described below for maximum beam at each 20 kV increment.**

4) **While watching the electrometer, use the fine adjustment knob to slowly increase or decrease the switching magnet setting until the beam current is maximized.**

5) **Continue to increase or decrease the terminal voltage in 20 kV steps, adjusting the magnet setting each time. Each time you have incremented the terminal voltage by 100 kV, adjust the following parameters, one at a time, to maximize the beam current on the electrometer.**

- **X Injector Steerer**
- **Y Injector Steerer**
- **X Quadrupole**
- **Y Quadrupole**
- **Ultrafine adjustment on Switching Magnet**



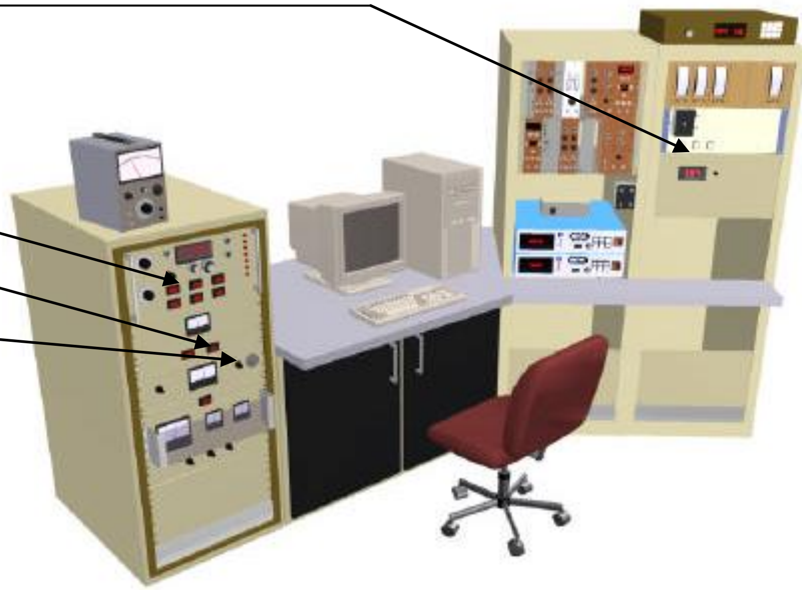
6) **Repeat steps 3-5 until you reach the desired terminal voltage you have calculated with the maximum beam current (20-40nA Typically).**

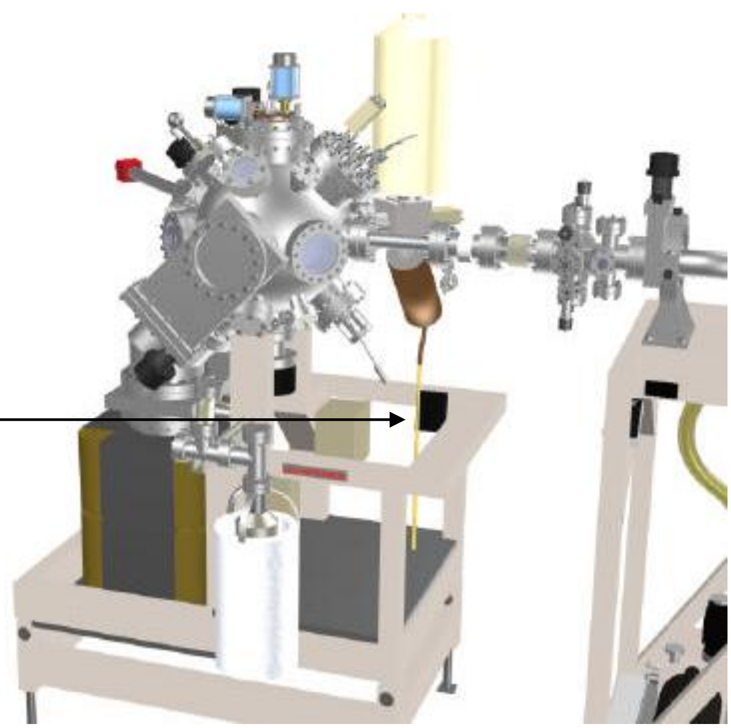
7) **Record your settings for Terminal Voltage, Magnet Setting, X injector steerer, Y Injector steerer, X Quadrupole, and Y Quadrupole on your tandetron logsheet.**

Tandetron Shutdown Procedure (Fill out Log sheet first)

Accelerator Shutdown

1) **Close RBS/PIXE gate valve.**
2) **Turn detector bias to 10V.**
3) **Turn terminal voltage down to zero slowly.**
4) **Turn off accelerator power**
5) **Close Isolation gate valve.**
6) **Turn switching magnet down to zero (Course and Fine knobs).**



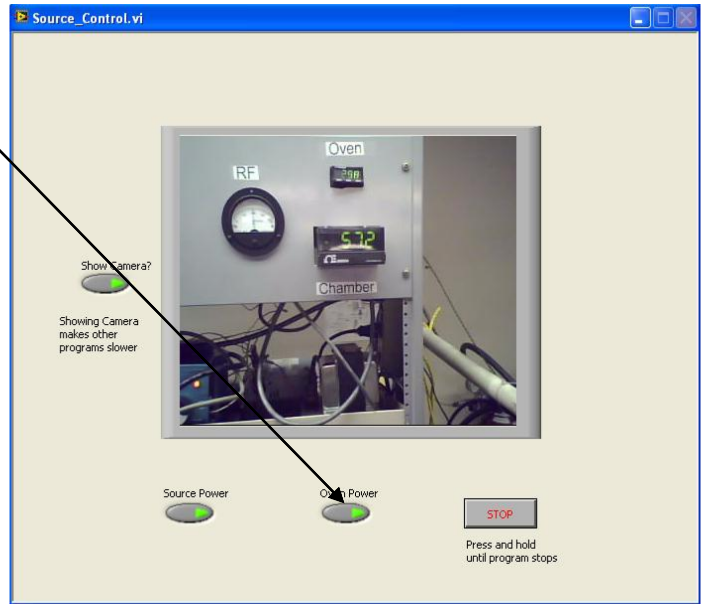


7) **Turn off the beam chopper.**

Continue to next page…

Gas Ion Source Shutdown

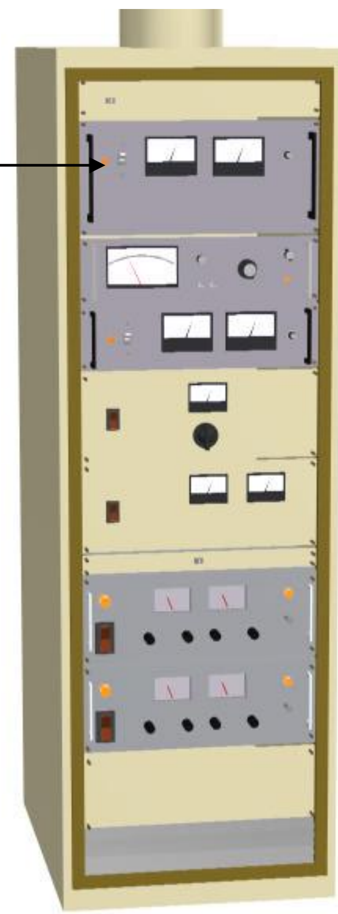
1) Turn off the Rubidium oven using Source_Control.vi.
   Select Oven Power (Green light should turn off).



**** If plasma is to be left on overnight ****
skip to step 3 and perform that step only.

2) Wait 25 minutes for Rubidium oven to cool.
   Oven temperature must be 50C or cooler before proceeding.

3) Turn off Pre-accelerator power switch by source cage



4) Open the Cage Door.
   This turns off all electronics in source area

The Shutdown Procedure is complete.

Make sure log sheet is completely filled out.

Section V

User Level III

Warm Start-up Procedure

Putting the Beam on Target

This Page Intentionally Left Blank

Warm Start-up Procedure

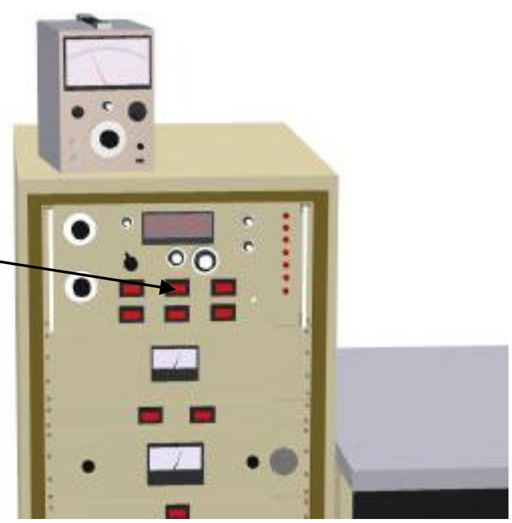
1) Check the vacuum in the beamline.

   a. Press 2 then 1/T. The vacuum should be less than $1x10^{-6}$ Torr.
   If it is greater, stop the procedure and contact Barry Wilkens.

   b. Open RBS gate valve and check the vacuum again. The vacuum should be less than $1x10^{-6}$ Torr.
   If it is greater, stop the procedure and contact Barry Wilkens.

   c. Open the isolation gate valve and check the vacuum again. The vacuum should be less than $1x10^{-6}$ Torr.
   If it is greater, stop the procedure and contact Barry Wilkens.

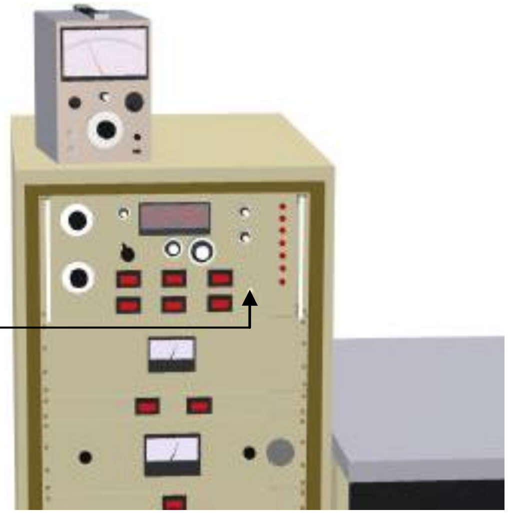
2) Turn on the accelerator power.



3) Turn on the quadrupole lens. Located under switching magnet.
(*These are usually left on*)

Continue to next page…

4) **Switch Faraday cup (F-cup) to “manual” and “in”.**

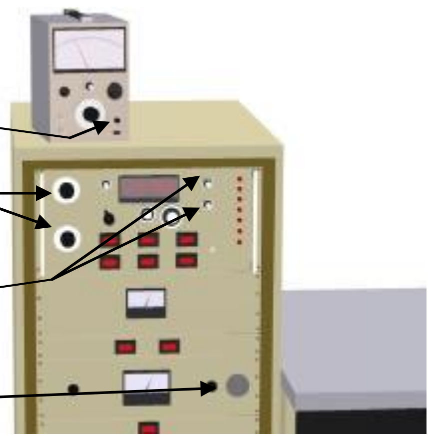


5) **Turn the terminal voltage up slowly. Watch the beam current monitor. The indicator should remain stable as you turn up the voltage. If it jumps up quickly, decrease the voltage by a few kV to prevent arcing. Continue to turn up the voltage to desired operating range**
Do not exceed 1.43 MV.

6) **Set ammeter to sensitive range, e.g. 2mA.**

7) **Using recorded values from a previous log sheet for your operating range, set values for:**

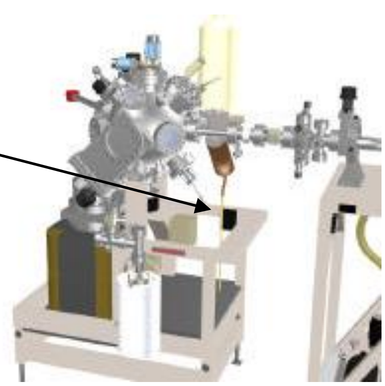
- **Injector steerer (X and Y)**
- **Quadrupole (X and Y)**
- **Switching Magnet**



8) **Turn on the beam chopper.**

9) **Turn on Stepper motor PS (restart LabView motor control)**

10) **Tilt sample holder approximately 30° - 40° away from load lock position to allow the beam to hit it.**



Alphatross Ion Source Start Up

1) **Check that cooling line valve is open to Alphatross and closed to sputter source. Check that coolant temp. (on floor in cage) is 21-22º C.**

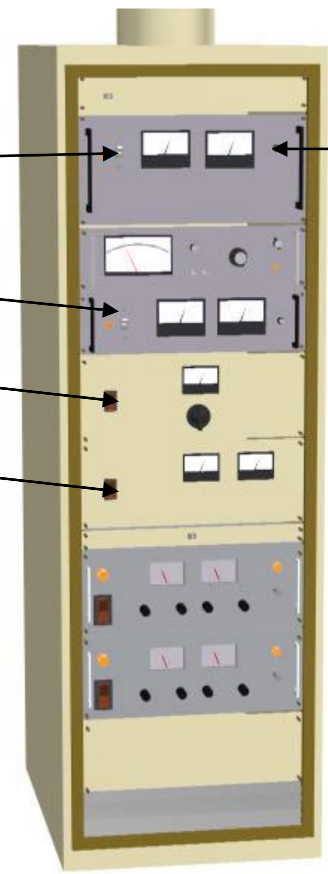
2) **Check that preaccelerator is turned off then close cage door to power up source electronics.**

3) **Note that probe voltage is on (6kV) and source magnet current is present (3.5-4A).**
Increase He gas until the overhead DVM reads approximately 1.5 - 2.5.
After 90-120 sec the plasma should ignite (aqua color when properly out gassed). Reduce He pressure until DVM reads approximately 1.0.

4) **Turn on Rubidium (Rb) oven using Labview Source control module on computer desktop. Allow the Rb oven to reach 290º - 310 º C (15 min).**
Eventually the chamber temp should reach 55º C

5) **Turn on:**

- **Pre-accelerator**
- **Grid Lens**
  (*usually on*)
- **Vertical Steerer**
  (*usually on*)
- **Injector Steerer**
  (*usually on*)



6) **Slowly turn up pre-accelerator voltage to approximately 40 kV.**

7) **Using recent setting of previous beam, put beam on the Faraday cup at entrance of chamber.**
(typical values ... 200nA)

Putting the Beam on Target

This section assumes that a sample has been properly loaded into the RBS chamber and that a beam current of 100-300 nA at the F-cup has been achieved. It is a continuation of the “Loading a Sample” section.

1) **After checking the Chamber pressure, open the RBS gate valve.**

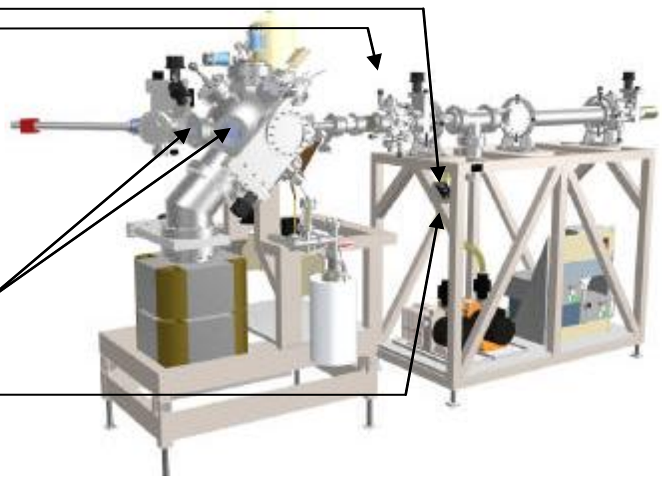
2) **Take Faraday cup out.**

3) **Turn on the laser and make sure it is hitting the sample.**

4) **Use the downstream collimators to adjust the size of the laser spot. Center slits around "zero" position.**

5) **After spot size has been adjusted cover all view ports.**

6) **Turn laser off.**

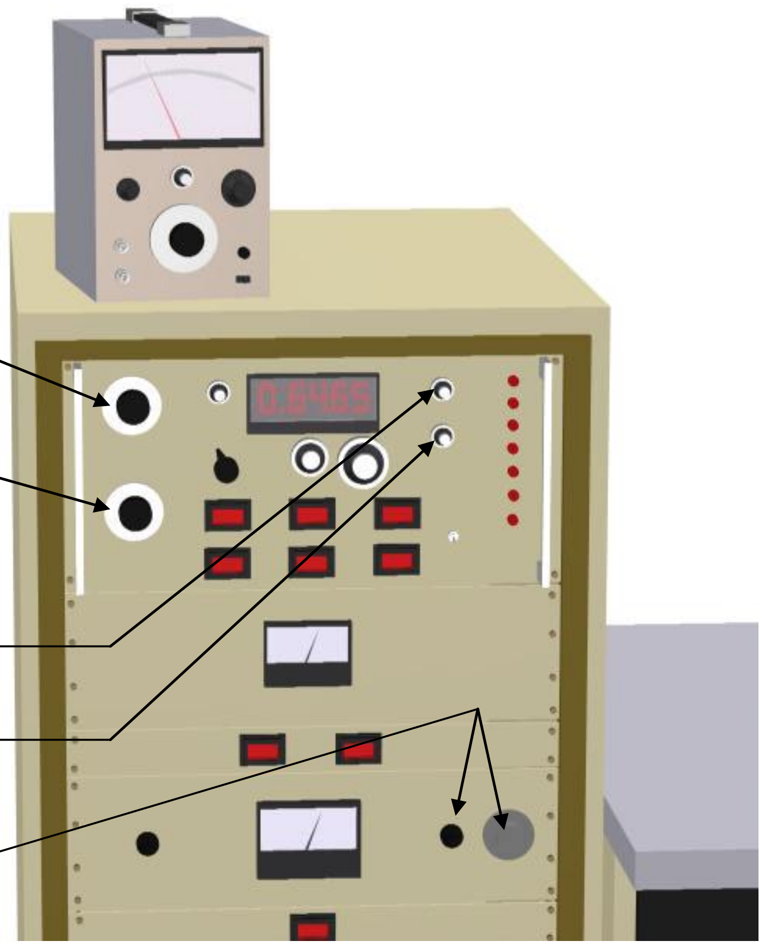


7) **Turn detector Bias up slowly to appropriate value.**

8) **Set the ammeter on a more sensitive setting (~ 2 µA). You should have a weak signal for the beam.**

9) **For your desired energy level, use previously recorded values for the following parameters as a starting point, and adjust them one at a time to maximize the current displayed on the ammeter:**

- **X Injector Steerer**
- **Y Injector Steerer**
- **X Quadrupole**
- **Y Quadrupole**
- **High Energy Switching Magnet**



Set the ammeter to the 20 nA or 200 nA scale. The ammeter should show a beam current of about 30 nA. Record your values for each of the parameters in step 9 on your log sheet.

You are now ready to acquire data.

This Page Intentionally Left Blank

Section VI

User Level IV

Switching from RBS to PIXE

Switching from PIXE to RBS

This Page Intentionally Left Blank

Switching from RBS to PIXE (860 Source)

Switching from RBS to PIXE and vise versa using Alphatross simply involves switching gas feeds to the leak valve after the Source has cooled

A) Turning off Alphatross and making connections in cage:

1. **Turn the Rubidium oven off. This is done by pressing the "oven power" button in the LabVIEW Source Control program so the . Green light means on, no green light means off. Wait until oven cools to 40º C or less (approx. 25-30 min.)**

2. **Turn preaccelerator voltage down to zero.**
3. **Open the cage door to shut off all of the electronics inside the cage.**
4. **Discharge the source electric cabinets and beam lines with the shorting hook. Connect the hook to nearby component(s) you are working on.**
5. **Turn off the He leak valve.**
6. **Turn on H leak valve (~4 1/4 turns). Check that H line is connected and that the gas is "on".**
7. **Switch source cooling by closing and opening appropriate valves at base with injector magnet table.**
8. **Switch the AC connectors in back of the source rack.**
9. **Confirm that correct source target is in 860 source (Ti plug end with H_2 feed) and turn on the H leak valve until DVM (pressure gauge) increases slightly.**
10. **Heat Cs reservoir with heat gun for about 1 minute to achieve a temperature of approximately 150°C.**
11. **Exit cage and close door which will allow source racks to power up.**

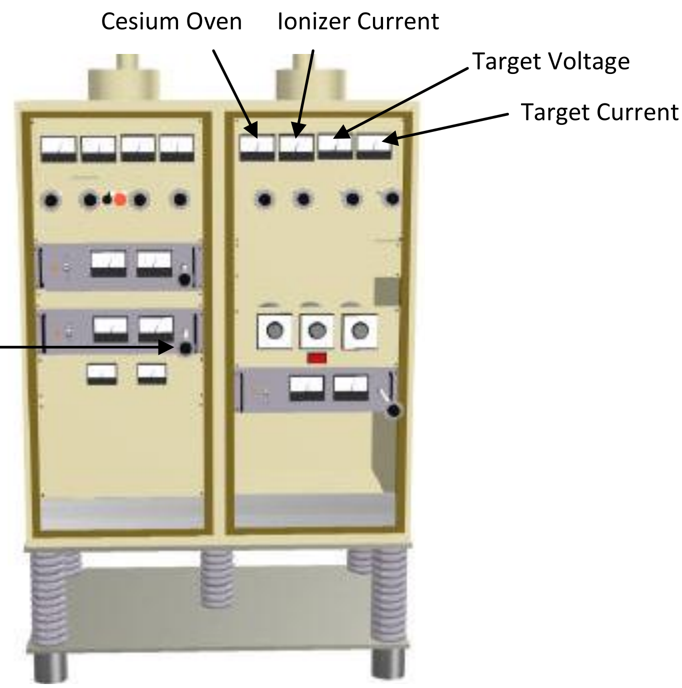
Continue to next page…

B) Source warm up process.

1. Turn Ionizer Current up, in 5A increments, to 20A. (will have to read just after 20 minutes).

2. Turn up Target Voltage to 3 kV.

3. Turn Extractor (-) to 5 kV.



C) Low energy Switching Magnet polarity.

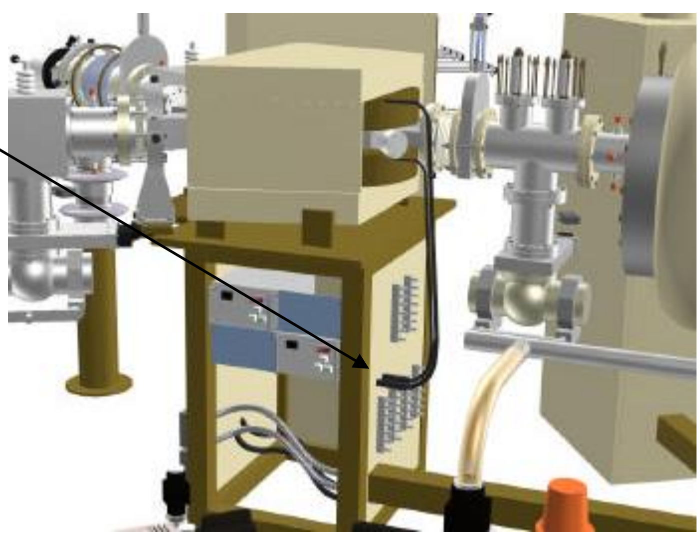
1. Turn Magnet power supply voltage down to 0V.

2. Turn off Magnet power supplies

3. Switch the black power cords. Plug the cord marked *PIXE* into port 1 and the cord marked *RBS* into port 2.

4. Turn top magnet power supply back on.

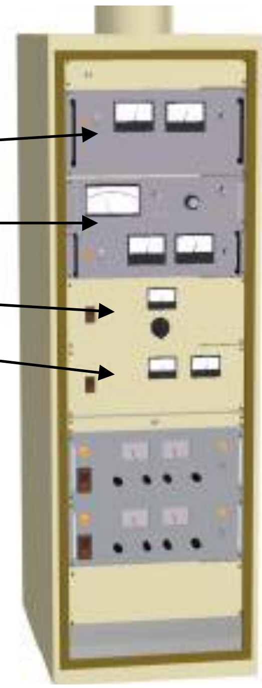
5. Turn top magnet power supply voltage up until you get 5A of current.



D) Bring up the source.

1. **Turn on the Following:**

   - **Pre-accelerator.**
   - **Grid Lens**
   - **Vertical Steerer**
   - **Power supply for injector steerer**



****Establish settings based on a previous PIXE run on log sheets****

2. **Turn Ionizer Current down to 17A.**
3. **Turn Target Voltage up to 3 kV.**

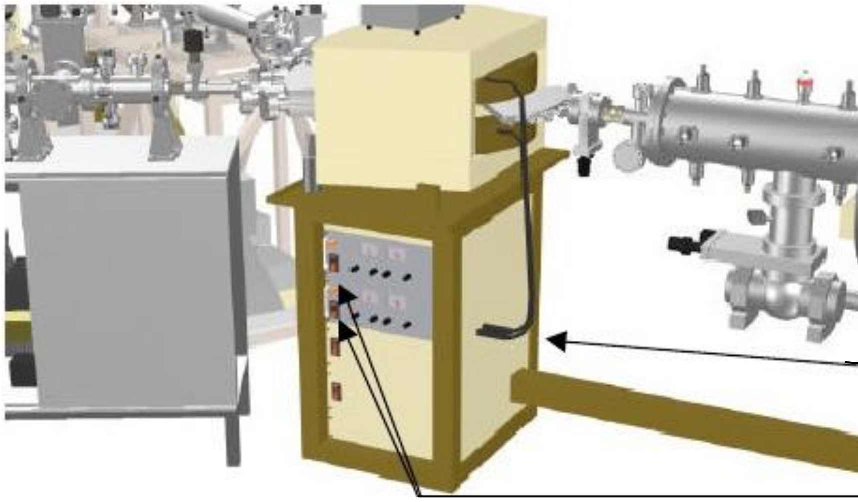
E) Find the Beam.

Adjust Pre-accelerator, Ionizer Current, Target Voltage, Magnet power supply, Grid Lens, Vertical Steerer, Einsel Lens and Extractor (-) voltage to maximize the beam current at the Farady cup as indicated in *Section V, User level III.*

Continue to next page...

F) High Energy Switching Magnet polarity.

(for switching to the External PIXE line)

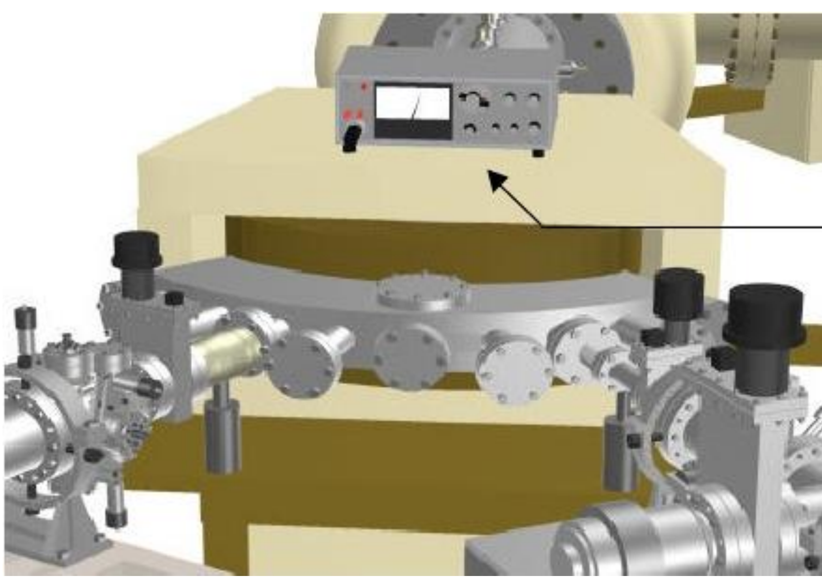


1. **Turn down Mag. power supply voltage to 0V Using the coarse and fine knobs on the accelerator control rack.**

2. **Switch the black power cords. Plug the cord marked *PIXE* into port 1, and the cord marked *RBS* into port 2.**

   ****Note: Gauss meter LED readout is now negative.**

3. **Set magnet to desired settings using Hall Probe read out. Maintain "extra fine" knob setting near max Clockwise position for most sensitive adjustments.**



G) Preparing the PIXE Beamline.

1. Make sure the vacuum in the PIXE line is below $1x10^{-6}$.
   If not, stop and contact Barry Wilkens.

2. Make sure Faraday cup is in.

3. Open the External beamline gate valve.

4. Connect the ammeter to the BNC connection for the copper target block inside the PIXE line. (Rotate target block to block beam)

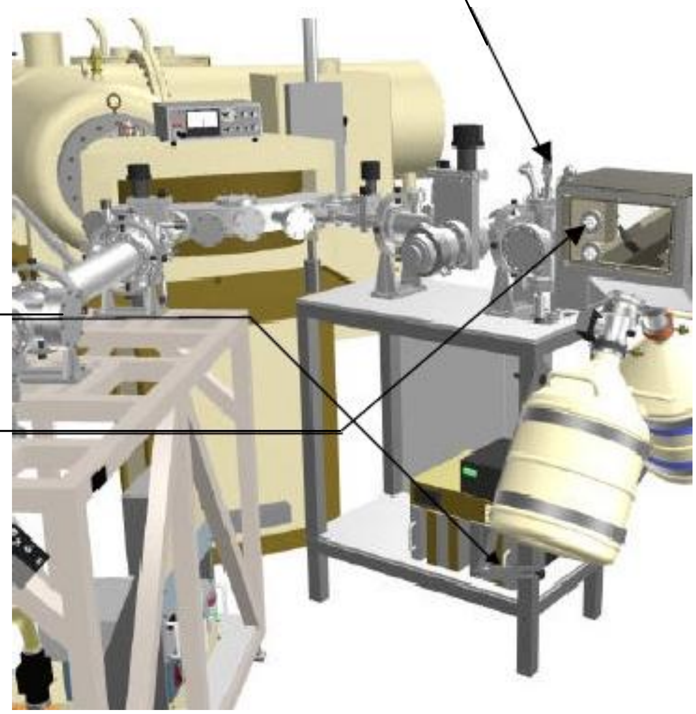
5. Adjust the beam parameters as in Section IV, User Level II, to maximize beam current with the electrometer (50nA Typical).

6. Slowly turn PIXE detector bias up to -480V.

7. Connect ammeter to Chamber-Target feed through BNC connector. Rotate copper block to allow beam to pass through.

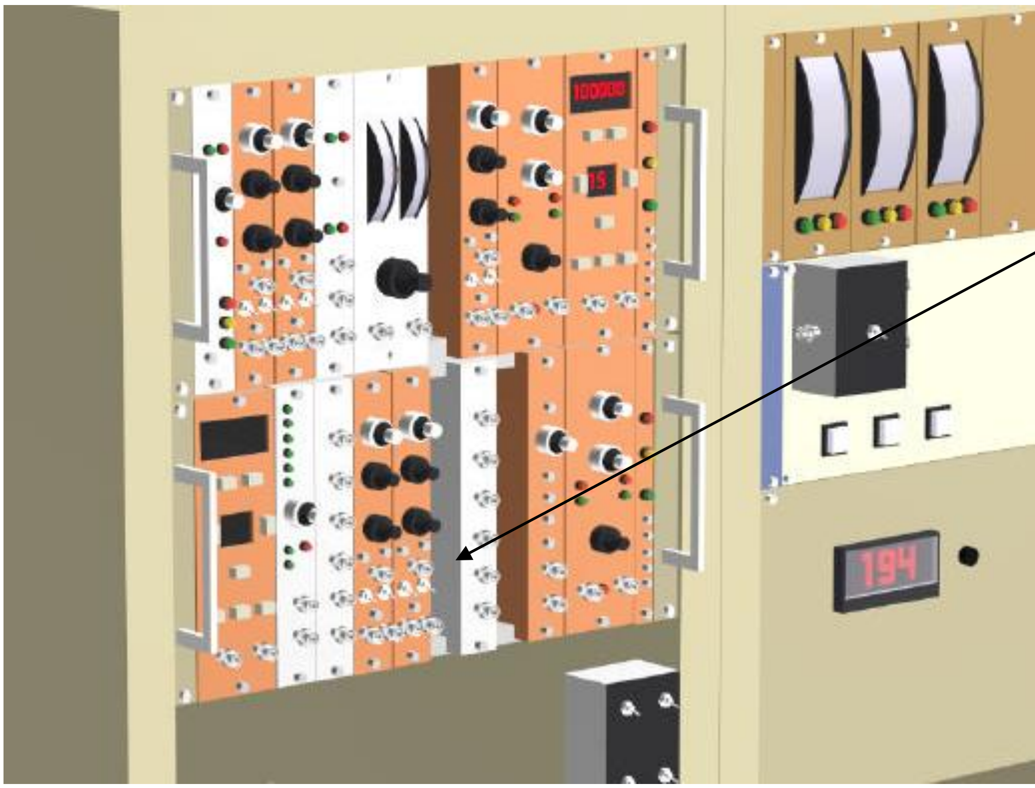
8. Put up safety rope to block access to target chamber.

9. Optimize beam on target.



Continue to next page...

10. **Set up appropriate gain and offset settings as well as enter necessary parameters into LabView Data Acclimation program.**



11. **Connect "Ex+ PIXE output" BNC connector to back of computer. Bypass DMR for best pile up reduction results.**

12. **Connect output cable from Beam sampling grid (at exit of beamline) to "chopper" cable to allow target current to reach charge digitizer and current integration circuit.**

!!! CAUTION !!!

Remember to put the F-cup "in" before putting your hand into the PIXE analysis chamber.

The accelerator is now set for PIXE Analysis.

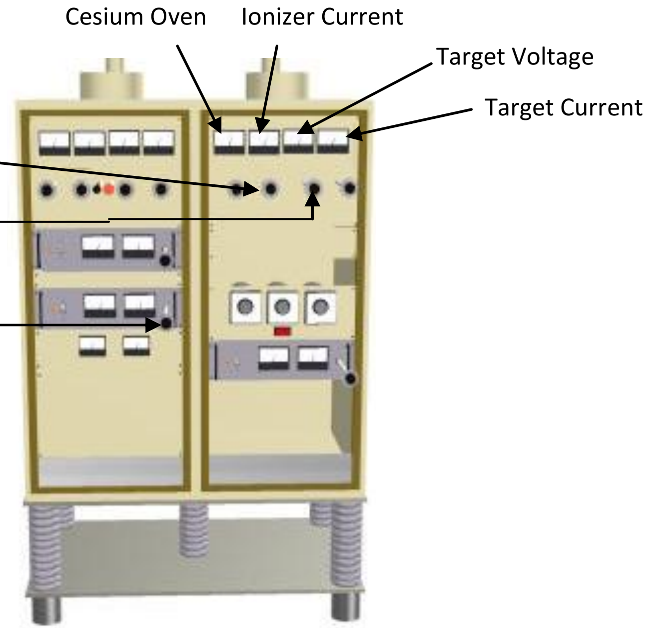
Switching from PIXE to RBS

A) Turn off PIXE Sputter Source.

1. **Turn Ionizer Current down, in 5A increments, to 0A.**

2. **Turn down Target Voltage to 0 kV.**

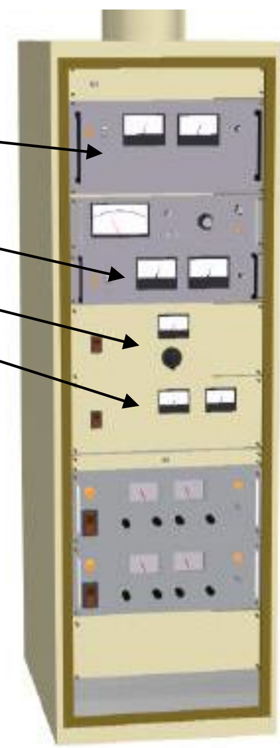
3. **Turn Extractor (-) to 0 kV.**



4. **Turn Pre-accelerator down to 0V.**

5. **Turn off the Following Components by cage door:**

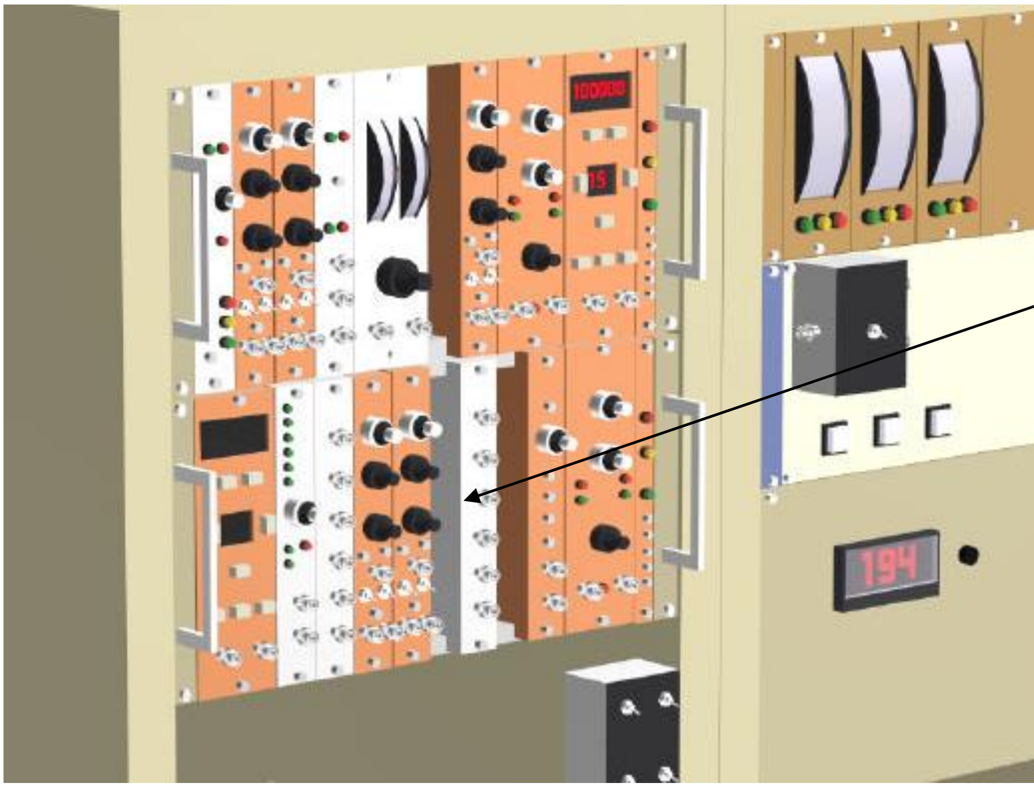
   - **Pre-accelerator**
   - **Grid Lens**
   - **Vertical Steerer**
   - **Power Supply for Injector Steerer**



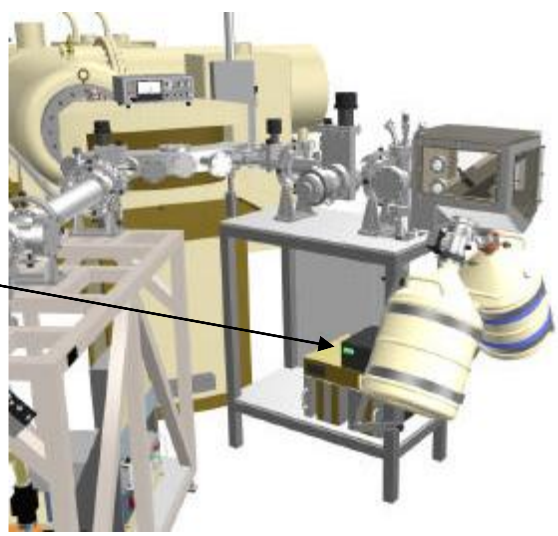
Continue to next page...

B) Electronics:

1. **At the Nimbin, connect the BNC cable labeled *RBS Signal* to the signal input of the ND570 ADC.**

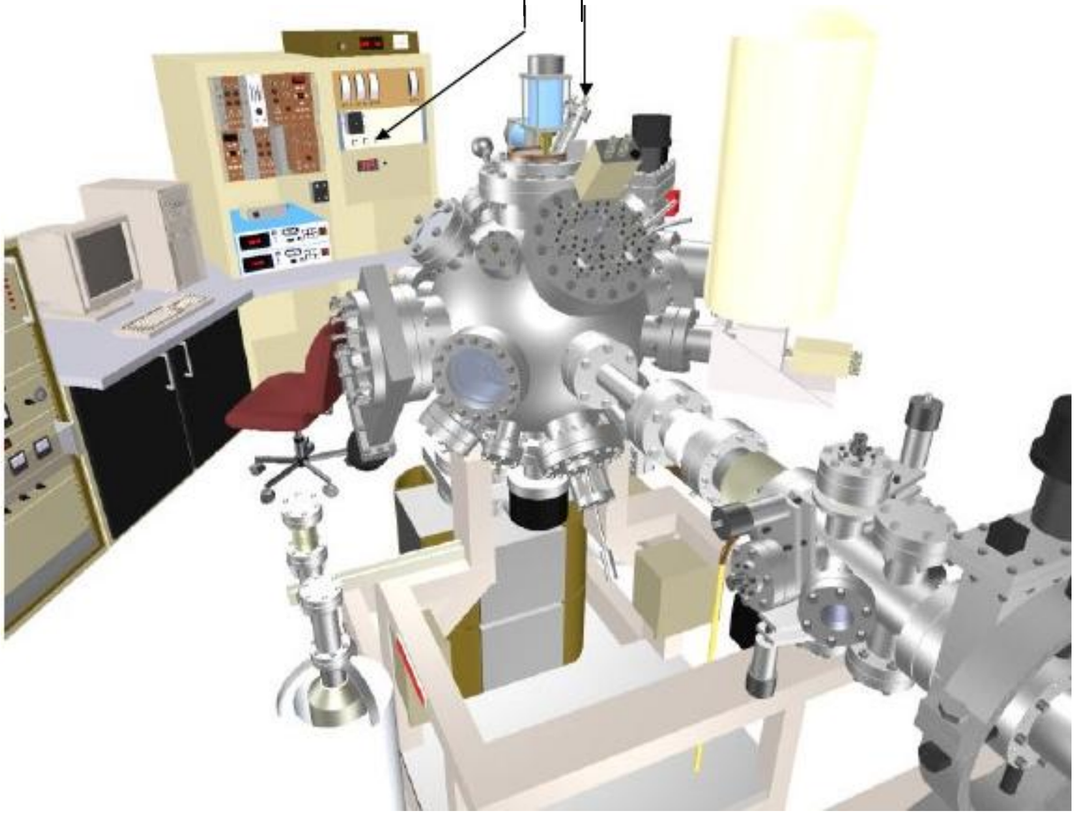


2. **Turn PIXE detector bias down to 0V.**



3. Disconnect the ammeter from the PIXE target chamber and connect it to the RBS end chamber.

4. Close External beam line gate valve.



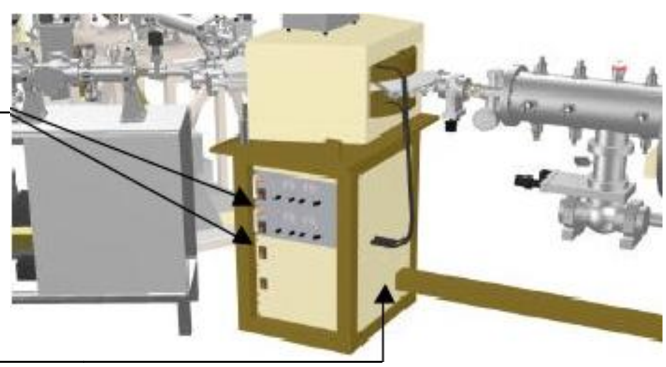
C) High Energy Switching Magnet polarity.

1. Turn down the magnet power supply using the controls on the accelerator control rack.

2. Turn off magnet power supply.

3. Switch the black power cords. Plug the cord marked *RBS* into port 1, and the cord marked *PIXE* into port 2.

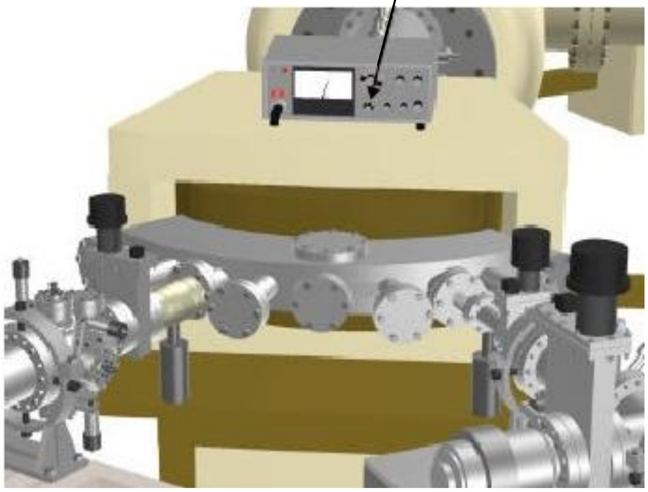
4. Turn on the magnet power supply.



Continue to next page...

5. Turn up the magnet voltage to obtain the desired settings on the digital readout of the Gauss meter.

6. Note gaussmeter readout is now positive



D) Inside Cage.

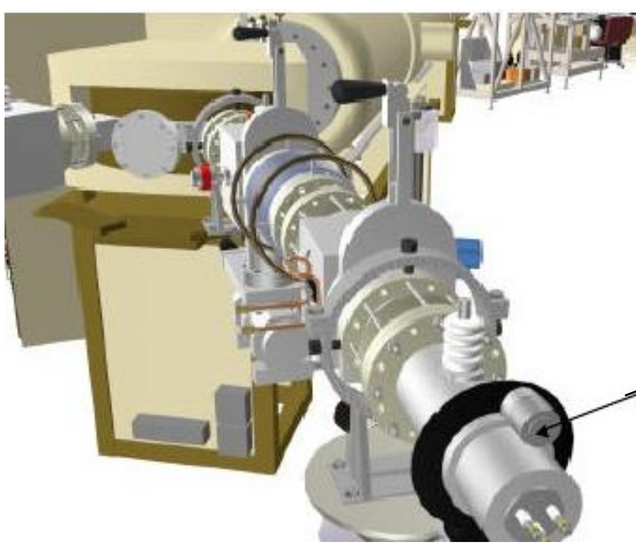
1. Open High Voltage Cage, Use Grounding Hook To Discharge any High Voltages on Source Components. Leave hook attached to any component you will be touching.

2. Change the low energy switching magnet cooling.

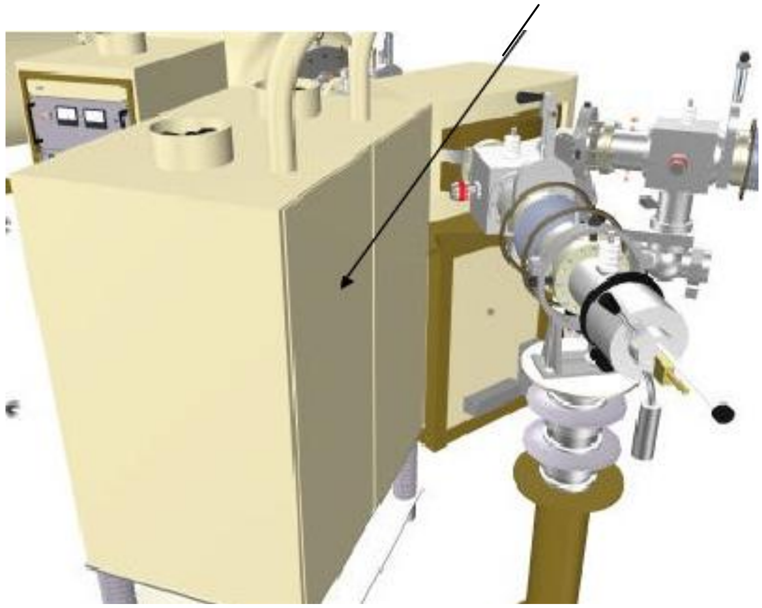
   - Turn the left handle to OFF.
   - Turn the right handle to ON.

3. Turn off the H2 leak valve on the 860 source.

4. Gently turn the He leak valve COUNTER-CLOCKWISE 4 1/2 turns to open the valve. Adjust valve slowly until pressure gauge to read about 1.6.



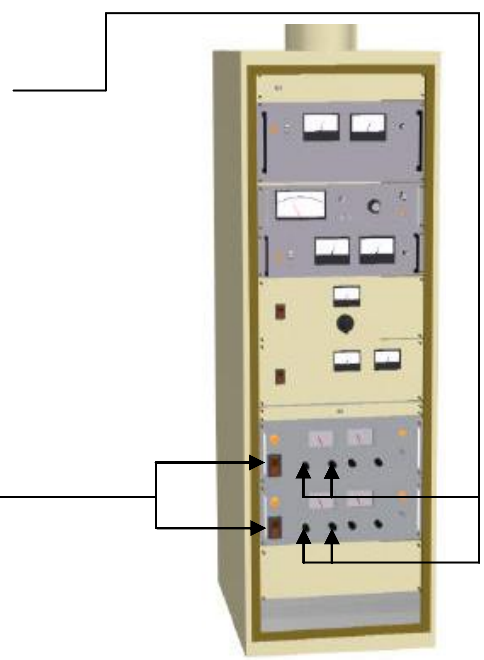
5. **Open Back panel of Sputter Source Control rack: Remove the 110 AC white plug marked *Sputter Source Power,* plug in 110 AC white plug marked *Plasmatron Power.* Gently close back panel of sputter source control rack making sure the interlock pin is not pushed in.**



6. **Remove grounding hook and close high voltage cage.**

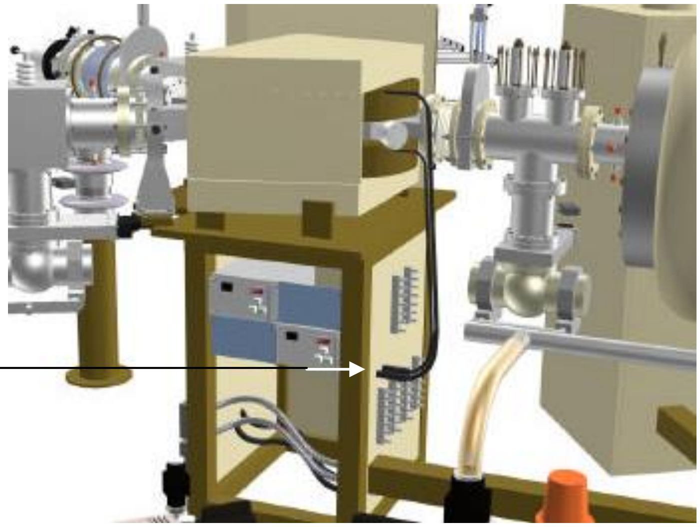
E) Low energy Switching Magnet polarity.

1. **Turn Magnet power supply voltage down to 0V.**
2. **Turn off Magnet power supplies.**



Continue to next page...

3. **Switch the black power cords. Plug the cord marked RBS into port 1 and the cord marked PIXE into port 2.**



4. **Turn Magnet power supply back on.**

5. **Turn Magnet power supply voltage up until you get a current of 10A.**

6. **Set extractor, probe, and sputter settings to typical values.**

7. **Cold Start Alphatross plasma by bringing up He gas pressure (approx. 4 turns on He leak vale)**

   Bring up probe voltage to 6kV. If plasma does not strike (indicated by probe current in the 1-2 ma range) increase the He pressure by approximately ½ to ¾ turns until probe current is observed. Reduce the He pressure for optimum probe current (1-2 mA). Follow instructions under "Warm Start" in Section V.

Section VII

User Level V

Ion Source and
General Accelerator Maintenance

See NEC Alphatross and General Ionex manuals for details on ion source and accelerator maintenance

This Page Intentionally Left Blank

Accelerator Maintenance Notes

The Tandetron is generally a low maintenance piece of equipment since there are no moving parts (except for Generating Voltmeter) inside of the tank. Most maintenance and repair issues are related to the ion sources, specifically the Alphatross source. Loss of beam can almost always be traced to Ion source problems, although there can be other issues related to vacuum or electrical failures elsewhere in the system.

Alphatros Ion Source (RF Source) Problems and Solutions:

1. Quartz tube contamination:
   Over time the quartz RF plasma tube can become contaminated, usually with Rb metal from the Rb charge exchange cell. This is manifested in a loss of beam and a dramatic increase in ion probe current (from 2-3 mA to >4mA causing voltage limiting to occur in the power supply). The only solution is to tear down the Alphatross and clean and replace several parts. This process is outlined in detail in the Alphatross instruction and operation manual.

2. Rb reservoir empty:
   A sudden increase in the Rb oven temperature along with a significant decrease in source output most likely indicates a low level of Rb in the crucible. This process requires an even more intensive teardown than what is described in the Quartz tube contamination section. The manual also explains this step by step process.

3. Ion current jumpy and unstable:
   Source contamination and oxidation can cause charging and discharging resulting in random deflection on the beam manifested in an unstable beam on the target. An area that is especially susceptible to this is the Gap Lens insulator. This can be diagnosed by noting a high current (voltage limiting) on the E-lens power supply. Again, the only solution is to disassemble the source and clean. The Gap lens problem can be bypassed by adding a high value bleed resistor in series with PS connection. This is only a temporary fix since ion source output is reduced by at least a factor of two as a result.

4. Poor vacuum:
   The result of poor vacuum is short lifetime of quartz tube and Rb reservoir due to the high partial pressure of oxygen.

5. The Al aperture can clog with Rb resulting in no beam output. This problem can be diagnosed by increasing the He gas feed and looking at the vacuum gauge for a corresponding increase in pressure. No change indicates a clog. Source must be disassembled and cleaned.

6. The Chamber (recirrculating) temperature is critical (55C +/- 1C). When temperature is too high Rb will not condense and run down into oven. When temp is too low Rb will freeze on walls of chamber. Adjust air cooling as needed.

860 Sputter Source Problems and Solutions:

1. Maximum source output depends on, among other things, Cs oven temperature and Cs level. Problems can occur if the Cs oven feed tube (to the source) is too causing Cs to condense and clog feed line. Cs oven temp. must be adjusted accordingly and care taken to ensure that feed line is being heated as well.

2. Other problems can occur when too much Cs or other contaminants coat the BN insulator on source target causing shorting of the target voltage. Solution: disassemble and clean source.Rb reservoir empty:

Accelerator Problems:

1. Terminal voltage limited:
   Inability to reach terminal voltages above 1MV might be due to worn RF tubes (in main PS). Solution is to replace tubes.

2. Terminal voltage instability at high settings:
   Poor vacuum in column and especially in terminal area causes fluctuation and poor voltage regulation. Solution is to check that turbo pumps are running at max RPM and vacuum is good.

3. Poor terminal voltage control:
   The Generating voltmeter and control logic board are the main components in this area.

4. Terminal voltage will not run-up:
   Inability to run-up terminal voltage can be due to problems with run-up relay and/or stepper motor controlled variac in main power rack. All of these and other problems can be helped by using the appropriate drawings and descriptions in the Tandetron manual set.

5. Maximization of beam transmission through the accelerator must be done with the F-cup aperture inserted for the correct injection geometry.

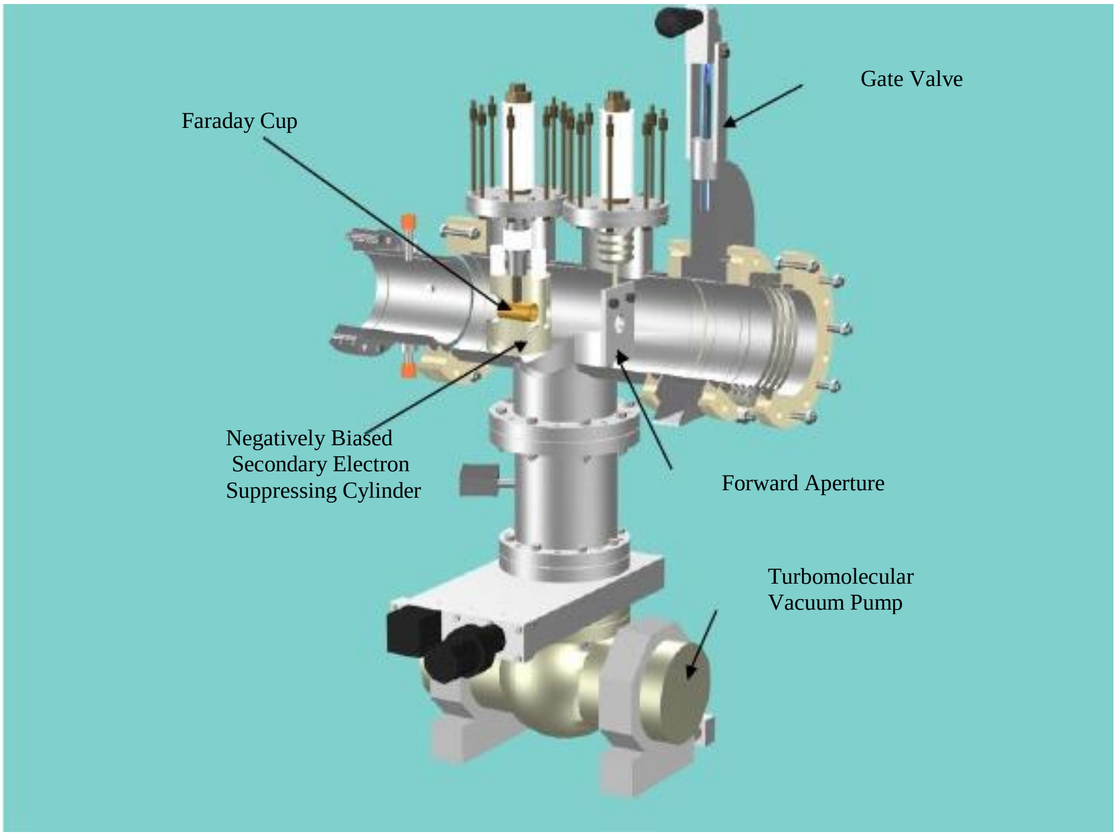
6. Adjust the stripper gas (nitrogen) for maximum beam. More gas for terminal voltages greater than 1MV and less gas for lower terminal voltages.

Appendix

Accelerator Diagrams

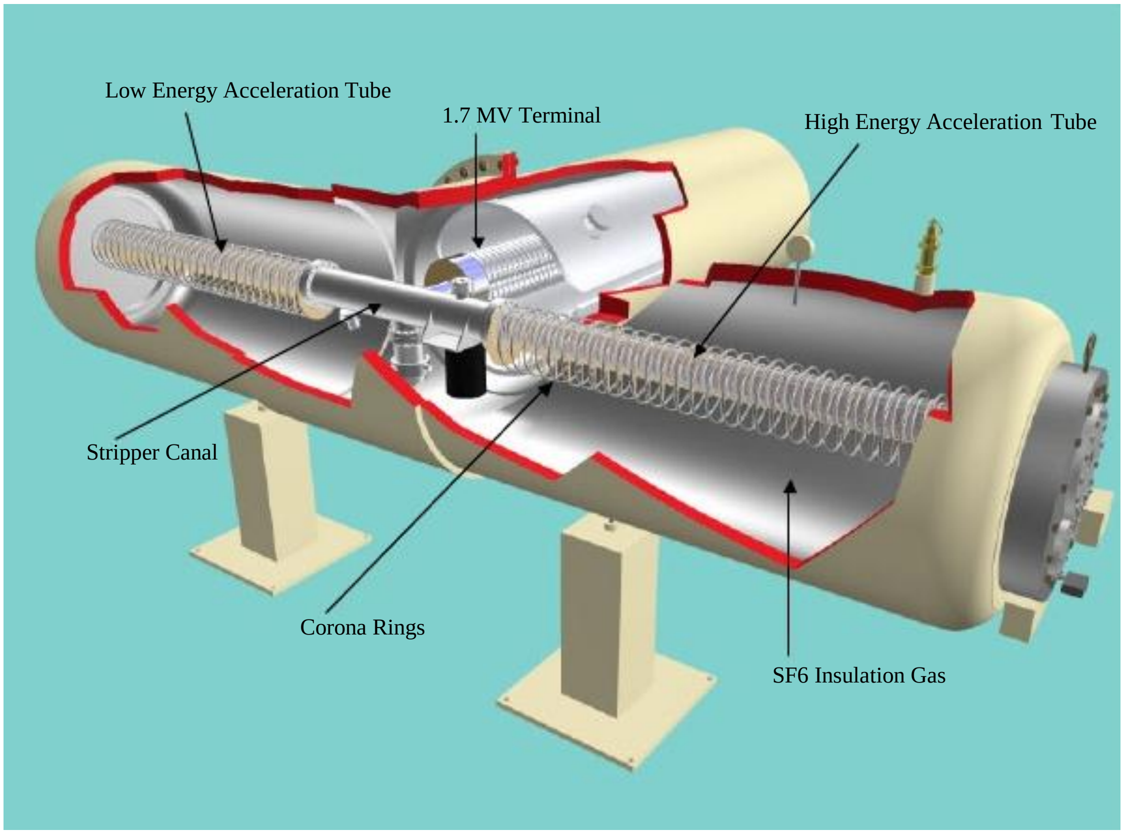
This Page Intentionally Left Blank

Faraday Cup Assembly



The Faraday cup is a conducting cylinder that is lowered into the beam of negatively charged particles. The length of the cylinder is typically three times the diameter in order to suppress most of the secondary electrons produced by the beam colliding with the back wall of the cylinder. The Negatively biased Secondary Electron Suppression Cylinder creates an electric
field which further suppresses the secondary electrons. The current of the beam plus the secondary electrons emitted can then be read at the current integrator. At present, we are using the apparatus without the negative bias. The suppression cylinder is grounded.

The Acceleration Tank



The Tandetron acceleration tubes are constructed by sandwiching titanium electrodes between glass insulating rings. The electrodes have a central hole which allows the ion beam to pass through several cutouts off the beam axis to improve the vacuum conductance of the assembled tube, and hold magnets to suppress secondary electrons. The assembled tube structure evenly distributes an applied potential by resistive grading. Resistive grading connects a resistor chain across each electrode and smoothly distributes the total voltage from terminal to ground. The uniform electric field needed for acceleration is produced only inside the acceleration tube and not at the entrance or exit of the tubes. The effect of the nonuniform field is to cause unwanted beam focusing, particularly for particles with low energies. Controlling beam-focusing changes as the potential across the acceleration tube changes is a major problem of optically matching the injector to the accelerator.

A gridded lens is used to match the optics of the ion source to those of the acceleration stage. The strength of this lens is adjusted by a variable external potential. It compensates for the electrostatic fringing field at the entrance to the acceleration tube.

A gas stripping region located in the terminal housing removes electrons from high energy particles. The negative ions from the low energy acceleration tube lose electrons in the stripper and become positive so that they are accelerated a second time down the high energy acceleration tube. Gas stripping is used in the Tandetron for good reliability and consists of a dilute target of gas atoms in a long thin tube. The inside diameter of the stripper tube is 6.35mm.

In any high voltage structure, electric stresses can be built up by corners or sharp edges on potential carrying components. The usual result of locally high electric stresses is local dielectric failure which causes either corona or sparking. To prevent high electric stress concentrations, it is important for any high voltage carrying component to look electrostatically smooth. The
function of the corona rings on the acceleration tubes and large radius corners or edges on other components is to reduce local electric stresses and thereby eliminate corona and sparking.

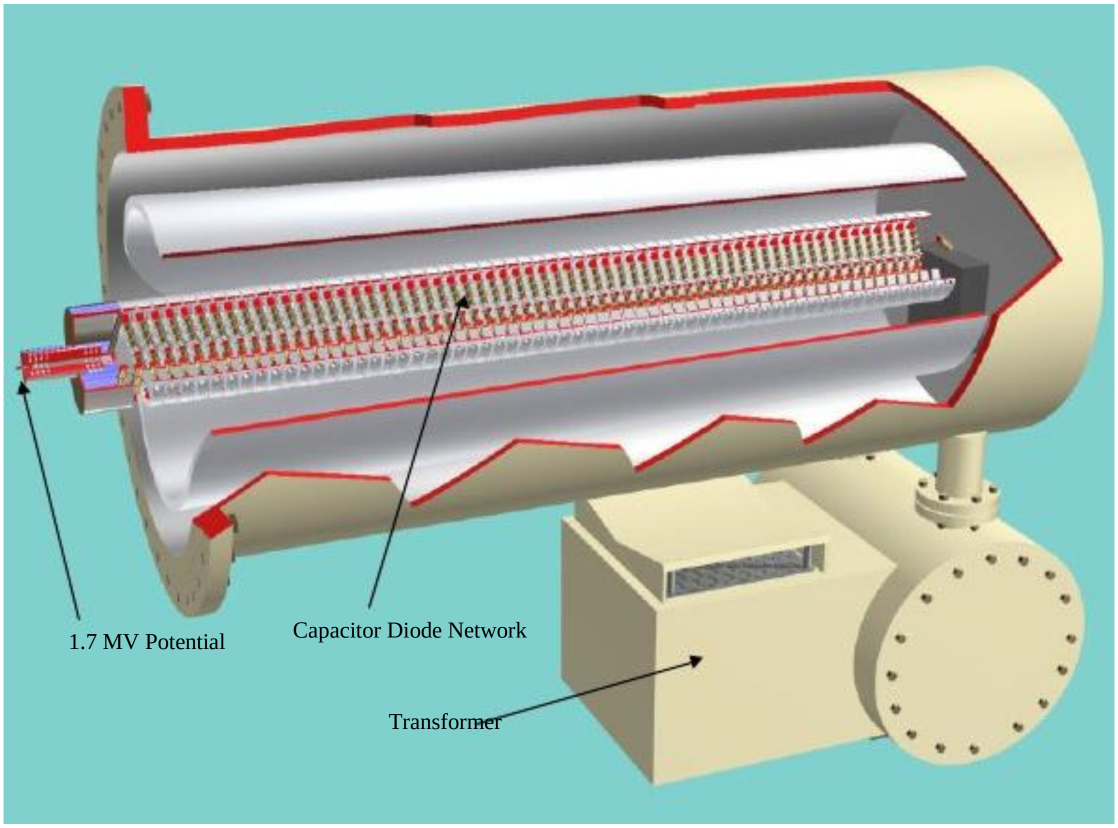
In order to maintain the high potentials and potential gradients inside the Tandetron, special attention must be paid to proper electrical insulation. Electrical insulation in the Tandetron is of three types: a) gaseous, b) solid, and c) vacuum. The electrical insulation must have sufficient dielectric strength and be properly shielded to prevent locally high stresses and surface tracking.

The gaseous insulation in the Tandetron is SF_6, a heavy, non-toxic, insulating material with a dielectric strength approximately 2.5 to 3 times the dielectric strength of air at the same pressure. To assure adequate dielectric safety margin, SF_6 is used at a pressure of 120 psig in the Tandetron where its dielectric strength is approximately 875 kV/inch. The apparently large safety margins are necessary to compensate for the impurities in the SF_6 such as air and water vapor, and to compensate for local stress intensification.

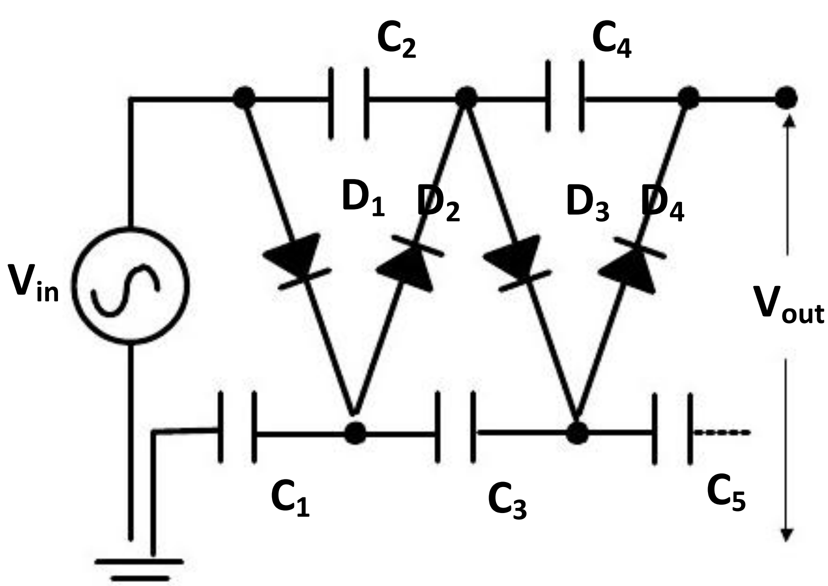
The solid insulation in the Tandetron consists of the glass insulators in the acceleration tubes, and the plastic support members in the power supply, and a variety of insulating materials which cover cables, or otherwise hold off voltage. While solid dielectrics have excellent voltage handling capabilities, they are subject to surface tracking failures and breakdowns caused by local material imperfections or local stress intensification. When solid insulation is used in the Tandetron, great care is taken to provide sufficient tracking lengths and to control local material imperfections and stress intensification by proper design.

Vacuum insulation is used inside the acceleration tubes and in the high energy extension of the Tandetron. When vacuum is highly electrically stressed, the materials in the vacuum chamber undergo a process called conditioning. Conditioning consists of field dependent currents, the magnitude of which depends on the condition of the cathode surface. Tarnished, water vapor covered, or microscopically rough surfaces produce a much higher conditioning currents than clean surfaces. The self-quenching, conditioning discharges apparently “smooth” the surfaces and allow higher potentials to be applied. When higher potentials are applied, a new round of conditioning begins which further smoothes the surface. Eventually, a voltage is reached where the discharges are no longer self-quenching and the voltage breaks down across the gap. Breakdown voltages vary from $1x10_4$ to $1x10_6$ V/inch vacuum depending on the electrode materials and the surface condition of the electrode.

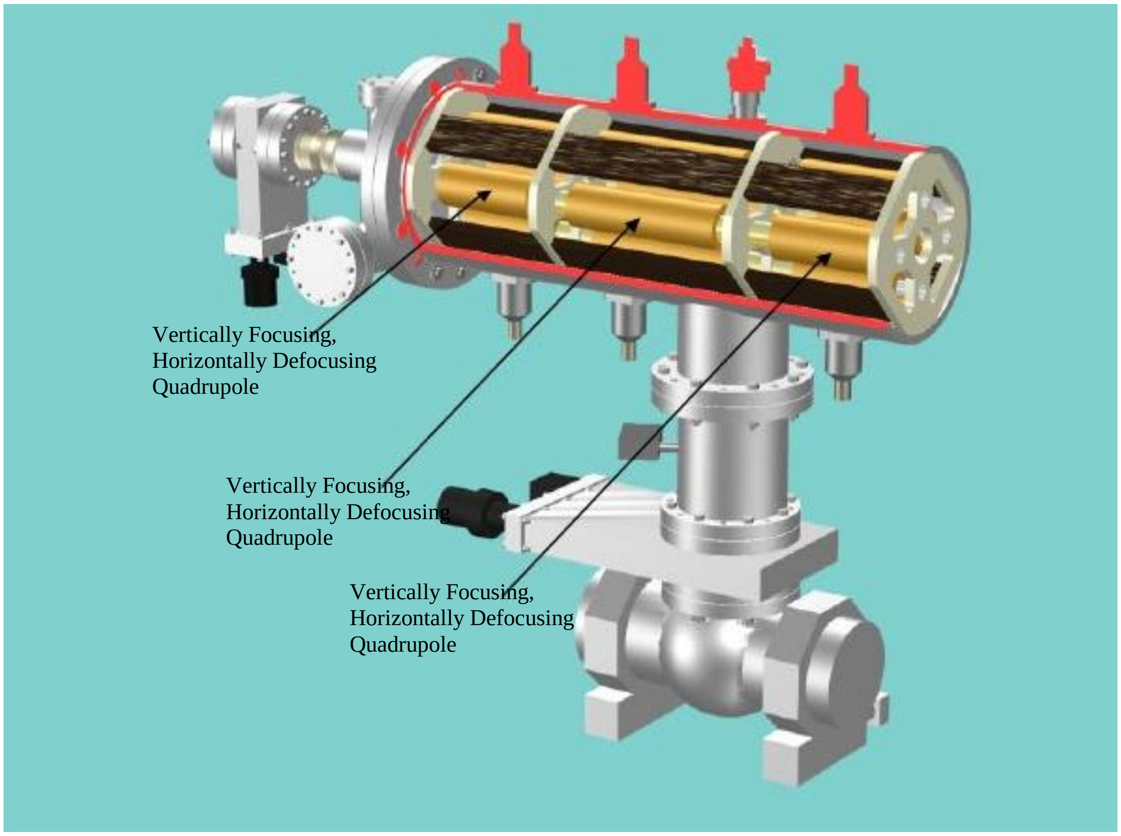
1.7 MV Power Supply



The 1.7 MV power supply is based on the Cockroft-Walton voltage multiplier. It consists of a series about 700 capacitor diode pairs where each pair doubles the input voltage. This Solid State power supply allows for stable voltage regulation with minimal maintenance. A Simplified circuit diagram is as follows:



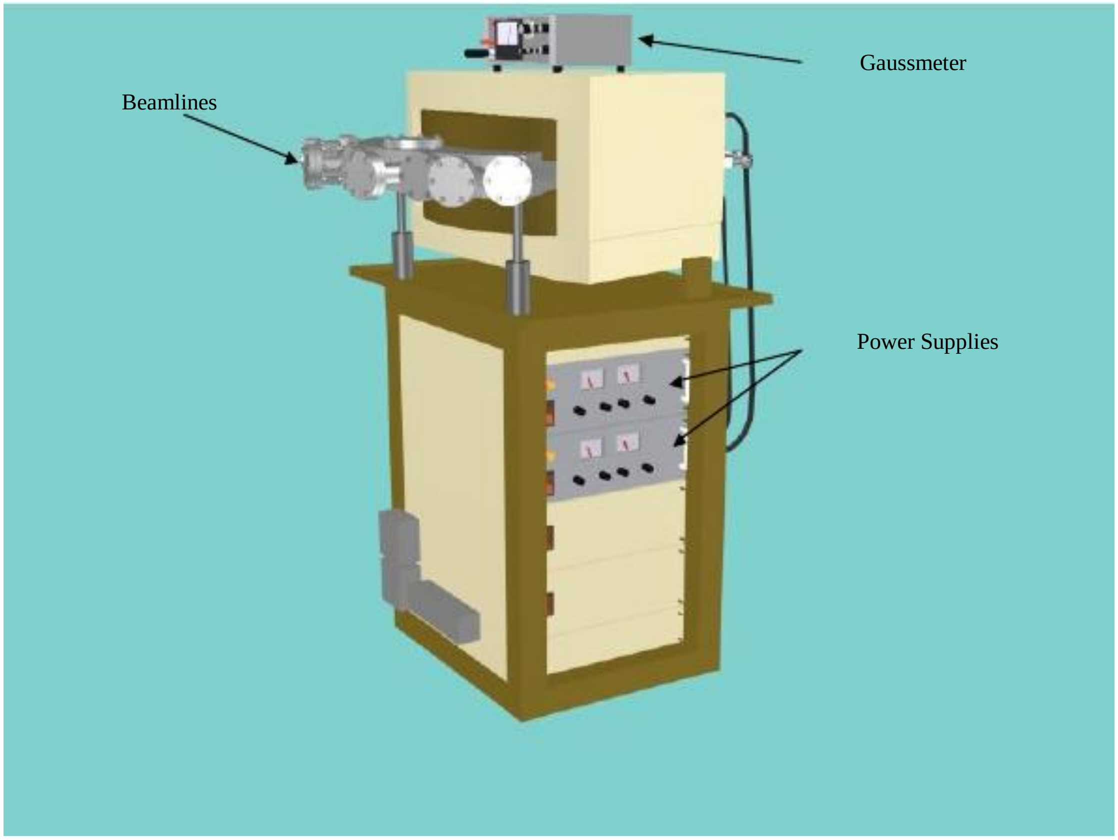
Quadrapole Lens



An electrostatic quadrupole triplet lens was chosen as the high energy focusing element because it provides strong mass independent focusing action with relatively low electric fields. Focusing in the quadrupole is determined by the geometry of the lens and the potential applied. The first and third quadrupoles are vertically focusing, horizontally defocusing. The second quadrupole is vertically defocusing and horizontally focusing. The net result is overall focusing. The clear aperture through the quadrupole is 1.75 inches in diameter.

The electrical hook-up is such that the opposing electrodes are of the same polarity. The two electrodes of the same polarity, for each quadrupole, are run by the same supply. The power supplies are programmed in pairs, so that by turning up the “Y” control potentiometer, the strength of the first and third quadrupoles increase. When “X” control potentiometer is turned up, both power supplies for the second quadrupole are increased.

High Energy Switching Magnet

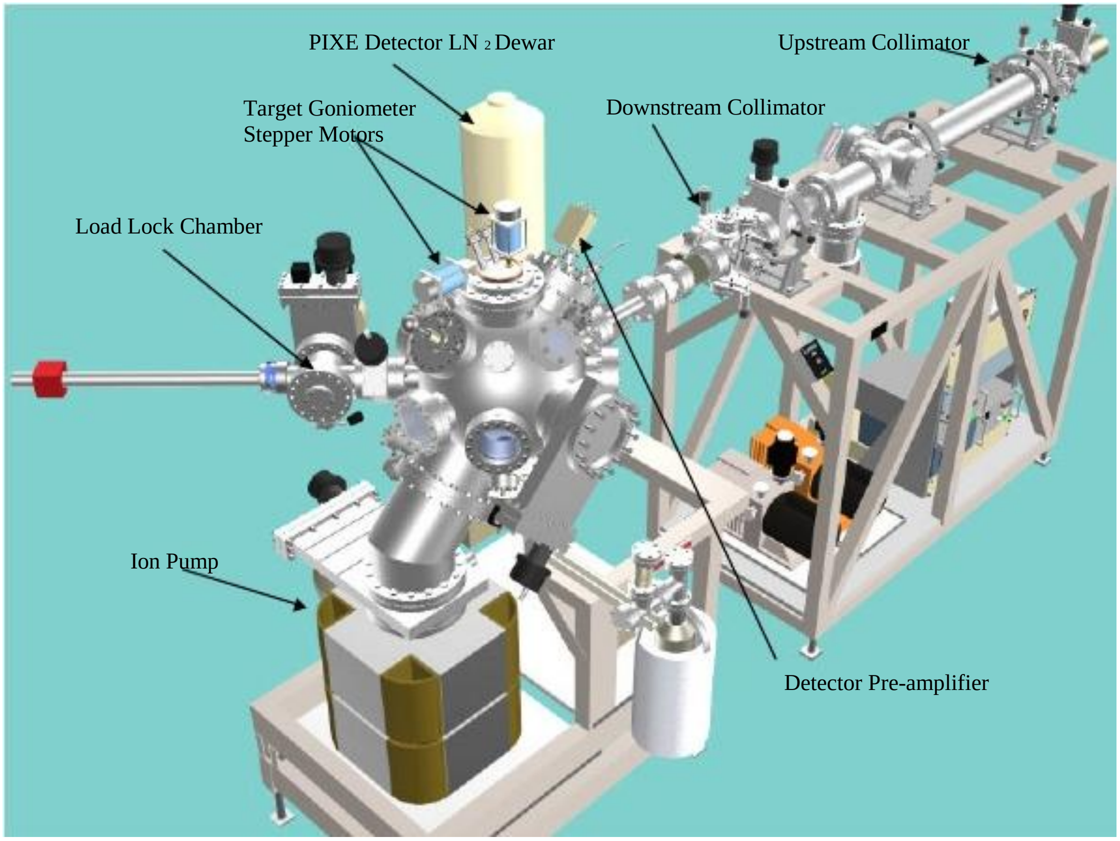


The magnet has a product 132 MeV-AMU at 15 degrees deflection. The radii of curvature of the trajectories are 55 inches (140cm) at 15 degrees and 27.5 inches (70cm) at 30 degrees. It has an aperture of 1.25 inches (3.18cm) and a maximum field of 11.6KG.

The vacuum chamber for this magnet has a special water-cooled baffle, so that high intensity beams deflected onto the baffle will not cause overheating. The baffle opening is 1.00 inches (2.54cm) high but 1.50 inches (3.81cm) wide, at the exit from the chamber.

The magnet is powered by a 40 volt, 50 ampere supply with a 100 millivolt current shunt for reading magnet current remotely.

RBS Analysis Line



Two sets of 4 jaw slits spaced 1.5 meters apart form a collimation system to define an ion beam for helium backscattering. The slits are opened and closed independently. The second set of slits, nearest to the scattering chamber, is also ventilated to allow better vacuum pumping of the collimator beam pipe.
When properly set up, the quadrupole triplet and switching magnet would be adjusted to form a beam waist at the center of the collimator. The slit openings can then be chosen to give beams of 1 to 3 mm diameter.

Excellent References for Further Reading on Ion Beam Analysis

Authors	Title	ISBN Number
Wei-Kan Chu James W. Mayer Marc-A. Nicolet	*Backscattering Spectrometry*	0-12-173850-7
S.A.E. Johansson J.L. Campbell	*PIXE a Novel Technique for Elemental Analysis*	0-471-92011-8
Leonard C. Feldman James W. Mayer	*Fundamentals of Surface and Thin Film Analysis*	0-444-00989-2
Leonard C. Feldman James W. Mayer S. Thomas Pieraux	*Materials Analysis By Ion Channeling (Submicron Crystallography)*	0-12-252680-5
James W. Mayer Eriksson Davies	*Ion Implantation*	Academic Press 1970
James W. Mayer E. Rimini	*Ion Beam Handbook for Material Analysis*	0-12-480860-3
Tesmer Nastasi Barbour Maggiore Mayer	*Handbook of Modern Ion Beam Materials Analysis*	1-55899-254-5