Project: Novel Electron Bubble Particle Detector

Procedure for Operating Columbia (Nevis) LHe Electron Bubble Chamber Cryostat

Version 5.0
(Using side filling line)

Hand Processed Changes

<table>
<thead>
<tr>
<th>HPC No.</th>
<th>Date</th>
<th>Page No.</th>
<th>Initials</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Approved: ___________________________ Date: ________________

5/31/2005
PROCEDURE FOR OPERATING NEVIS LHE EBC

1. Purpose

1.1 This Operating Procedure Manual provides instructions for operation of the Columbia (Nevis) LHe Electron Bubble Chamber (EBC) System, with explanation of the LHe/LN₂ Cryostat and associated infrastructure involved.

1.2 The Operating Procedure set forth here is required for the safety of the system and of the operators. All participants in the operations must study the Operating Procedure Manual.

1.3 The Log Book for operations must indicate which version of the Operating Procedure Manual is being followed at the time; who is in charge of operations at any given time (Chief); and who else is assisting. All significant conditions in the system and changes must be noted in the Log Book.

2. Responsibilities

2.1 It is the Chief operator’s responsibility to ensure that all operators have the appropriate training, and that all procedures in this Manual are followed.

3. Prerequisites

3.1 All operators must have received the required BNL Training prior to working with the LHe EBC System, and have studied this Operating Procedure manual.

4. Precautions

4.1 Be sure that all necessary system components are functioning correctly prior to start-up.

5. Procedure

5.1 BEFORE START-UP

5.1.1 Make sure that the vacuum jacket of the LHe transfer line has been properly evacuated. Periodic re-evacuation of the transfer line jacket is necessary for efficient LHe transfer.

5.1.2 Be sure that all valves (vacuum, ball and globe) except ball valve 16 on the LHe Dewar are closed, and that all relief valves are installed on the LHe Dewar, LN₂ Dewar, Pumping port and Cryostat.

5.1.3 Do not open any valves if there is below 0 (psig) pressure indicated on the pressure gauges P4 and P5 on the LHe Dewar and LN₂ Dewar. This would allow air to rush into the Dewar and form an ice plug.
5.1.4 Be sure to wear safety glasses and insulated gloves when handling liquid helium and nitrogen.

5.2 **EVACUATION OF LHE/LN\textsubscript{2} CRYOSTAT VACUUM JACKET**

5.2.1 Connect the flexible coupling from the **turbo-pump (TP1)** to the **connector of vacuum valve 103** extending from the Cryostat.

5.2.2 Open **vacuum valve 103** and **101** on the top of **turbo-pump (TP1)**, turn on the **turbo-pump**, and evacuate the cryostat vacuum jacket until the pressure at the pump drops to $1 \times 10^{-5}$ torr or less, as measured by the **ionization gauge (TC5)**. It is recommended to evacuate the system overnight before operating.

5.2.3 Do not introduce cryogen into the chamber with the evacuation valve open when the pump is turned off. This may cause cryopumping of vacuum pump oils into the Cryostat vacuum jacket.

5.3 **GAS PURIFICATION**

5.3.1 Open the **globe valve on gN\textsubscript{2} cylinder**, and set its regulator at 85 psi (100psia), which is needed to provide the high pressure of gN\textsubscript{2} to operate the **Purifier**.

5.3.2 Open the globe valve and additional valve on the gHe (or gNe) cylinder, and set its regulator at 30 psi, then open the **valve 34** (for gHe) or **valve 35** (for gNe).

5.3.3 Switch on the power of **Purifier** (the power button is located on the right side), the controller will perform an auto-test, and three **LEDs** will illuminate on the front panel:

- **HEATER**: STANDBY
- **VALVES**: BYPASS
- **TEMPERATURE**: LOW

5.3.4 The **Purifier** is now at room temperature. Open **valve 32, 30 and 9**, then open slightly **valve 7**. The purge gas (Ne or He) is flowing slowly through the **BYPASS** of **Purifier** and is venting out through **Bubbler** (checking bubble) to atmosphere.

5.3.5 After about 10~15 min, push the **HEATER ON/OFF** button to start heating the **Purifier**, the **HEATER** status will change to **OPERATING** and the **VALVE** status will change from **BYPASS** to **PURIFY**.

5.3.6 It will take about 30-45 min for the **Purifier** to reach working temperature (LOW to SET, ready to purify the gas

5.3.7 Open **valve 33 and 31**, then close **valve 32**. Open the valve of the **Flow Meter** and set its at ~2.5 CFH

5.3.8 After about 2~3 min, close **valve 9 and 7**, now the gas flowing from the **Purifier** is pure to fill into e-bubble chamber.

5.3.9 After finish gas filling, close **valve 30** and push the **VALVE CONTROL** button to change its status from **PURIFY** to **BYPASS**.

5.3.10 Push the **HEATER ON/OFF** button to change its status from **OPERATING** to **STANDBY**.

5.3.11 **TEMPERATURE LED** will change to LOW after several minutes.

5.4 **EVACUATION AND FILLING e-BUBBLE CHAMBER AT DESIRED TEMPERATURE**
5.4.1 Before filling e-bubble chamber, make sure to evacuate the central tube by Turbo-pump (TP2) for about 30 min, then close firmly valve 8.

5.4.2 Open valve 25, 27 and 28, turn on Turbo-pump (TP2) to evacuate the side transfer tube, e-Bubble chamber and gas transfer line for about 10 min and open valve 26.

5.4.3 After 10 min, turn on the emission of UHV ionization gauge (TC7), which can only start to work at vacuum below $10^{-3}$ torr, to check the vacuum until the vacuum drops below $10^{-5}$ torr.

5.4.4 Close valves 26 and 27, and turn off Turbo-pump (TP2). 

5.4.5 Open valve 30 and allow the pure gas (He or Ne) entering the e-Bubble chamber through the side transfer tube until the pressure transducer P3 reaching 4 psi, close valve 28 and 30.

5.4.6 Open valve 27 and turn on the Turbo-pump (TP2) to evacuate the side transfer tube, e-Bubble chamber for about 10 min and open valve 26.

5.4.7 Repeat the procedures of 5.4.2 and 5.4.3.

5.4.8 Open valve 30 and 7, then open slightly valve 9 and allow the pure gas (He or Ne) purge the transfer line for 2 min.

5.4.9 Close valve 7 and 9, then open slightly valve 25 and allow the pure gas (He or Ne) entering the e-Bubble chamber through the side transfer tube until the necessary pressure, measuring by Pressure transducer P3.

5.4.10 Close firmly valve 25 and 28, the e-Bubble chamber are filled with pressurized pure gas.

5.4.11 To reach small temperature gradient of e-bubble chamber, fill small amount of helium gas into central tube by checking pressure transducer P2 to decrease the temperature gradient of T4 and T5 on the top and bottom flange of e-bubble chamber.

5.5 PUMP/PURGE LHe VESSEL AND COOLING CIRCUIT

5.5.1 Never evacuate the LHe vessel unless the Cryostat vacuum jacket has been previously evacuated, collapse of the LHe vessel wall may occur.

5.5.2 Insert the SS filling tube though helium fill port (C1) into LHe vessel until it reaches the bottom, then rise slightly and seal helium fill port C1.

5.5.3 Connect a Teflon transfer hose to the SS filling tube and connect the other end to the quick connector C19 on the LN2 Dewar.

5.5.4 Open ball valve 1, 2 and 4 on the control panel.

5.5.5 Open ball valves 104 and helium needle valve 105.

5.5.6 Turn on Turbo-pump (TP2), to evacuate LHe vessel and flow passage through the needle valve, capillary tube and cooling circuit loops, until the pressure drops below 0.1 torr (TC2) to remove any air or moisture.

5.5.7 Close ball valves 104, 1, 2 and 4, and turn off the Turbo-pump (TP2).

5.5.8 Set regulator valve 12 (on the gHe bottle) at 0.5~1 psig, and open ball valve 10, allowing helium gas into the LHe vessel.

5.5.9 After 30 seconds, close ball valve 10 and helium needle valve 105. The LHe vessel is now pressurized (0.5~1 psig).
5.5.10 Close needle valve 11. Be sure to close ball valve 22 on helium vent port C2 of the LHe vessel to prevent air and moisture from entering the vessel.

5.6 **PRECOOLING LHe VESSEL WITH LN\textsubscript{2}**

5.6.1 Open globe valve 20 on the LN\textsubscript{2} Dewar, this valve can be adjusted (1/4~1/2 turn) to obtain the proper liquid flow rate.

5.6.2 Open ball valve 22 on the helium vent port (C2). Liquid nitrogen will be transferred into the LHe vessel directly from the pressurized LN\textsubscript{2} Dewar.

5.6.3 During this cool down, open occasionally the helium needle valve 105, by approximately 3~5 turns, to let LN\textsubscript{2} enter the needle valve, capillary tube, and cooling circuit loops. This procedure also prevents the needle valve from freezing shut as it is being cooled along with the rest of the LHe vessel.

5.6.4 After about 15 min, when T1 on the bottom flange of LHe vessel drops below 81K, it indicates that there are some LN\textsubscript{2} cumulated inside LHe reservoir. From then on it takes about 10 min to fill ~10 liters of LN\textsubscript{2}, which are sufficient to precool LHe vessel.

5.6.5 Close globe valve 20 on the LN\textsubscript{2} Dewar.

5.6.6 Wait several minutes to let LN\textsubscript{2} calm down, disconnect the Teflon transfer hose from the SS filling tube.

5.6.7 Lift slowly the SS filling tube out off helium fill port (C1) on the LHe vessel, and seal helium fill port (C1) by rubber stopper

5.6.8 Close ball valve 22 on the helium vent port (C2) to prevent air and moisture from entering LHe vessel, LN\textsubscript{2} vent out through relief valves R4 (0.5 psig).

5.6.9 Keep the Teflon transfer hose on the quick connector 19 of the LN\textsubscript{2} Dewar.

5.7 **LIQUID NITROGEN FILLING TO LN\textsubscript{2} VESSEL**

5.7.1 Insert the Teflon transfer hose though one of the nitrogen fill/vent ports (A1) into the LN\textsubscript{2} Dewar until it reaches the bottom.

5.7.2 Open globe valve 20 on the LN\textsubscript{2} Dewar, this valve can be adjusted (1/4~1/2 turn) to obtain the proper liquid flow rate.

5.7.3 LN\textsubscript{2} will be transferred into LN\textsubscript{2} vessel directly from the pressurized LN\textsubscript{2} Dewar, while venting though the other two nitrogen vent ports (A2 and A3).

5.7.4 Approximately 40~45 liters (~30 min) of LN\textsubscript{2} is needed for this cool-down and fill.

5.7.5 When the LN\textsubscript{2} starts to be visible from one of the nitrogen vent ports (A2 or A3), close globe valve 20 on the LN\textsubscript{2} Dewar.

5.7.6 Record readings on temperature T10 and T11 periodically during steps 5.6.3 through 5.7.1.

5.7.7 Remove the Teflon transfer hose from nitrogen fill/vent tubes (A1) on the LN\textsubscript{2} vessel and seal it with rubble stopper. Nitrogen vapor will vent through the other two nitrogen vent ports (A2 and A3).

5.8 **LOWER TEMPERATURE OF E-BUBBLE CHAMBER**
5.8.1 Adjust the **needle valve operator 105** at the top flange of the cryostat to change the LN$_2$ mass flow rate entering the **cooling circuit loops** from the LHe vessel.

5.8.2 Open **helium needle valve 105** 3~8 turns, and open **ball valves 3 and 4** on the control panel, in this case helium vapor will vent out directly to atmosphere through **check valve R12**. The venting flow rate can be monitored either by **flow meter FM1** or **FM2** on control panel.

5.8.3 Monitor **temperature drops of T4, T5, T6, T7, T8 and T9** around the e-Bubble chamber.

5.9 **REMOVE LN$_2$ FROM LHe VESSEL**

5.9.1 Wait and allow LN$_2$ to completely cool **LHe vessel** and **e-Bubble chamber** to lower than 80K (~several hours) by checking **temperature T4, T5, T6 and T9**.

5.9.2 Insert the **SS filling tube** though the **helium fill port (C1)** into **LHe vessel** until it reaches the bottom and connect a Teflon tube to it.

5.9.3 Set **regulator valve 12** on the **gHe bottle** at 2~5 psig. Open **needle valve 11** and **ball valve 10**. Admit warm gas helium into the **LHe vessel**.

5.9.4 Seal relief valves R4 (0.5 psig) by relief valves R5 (4 psig) to allow pressurization.

5.9.5 LN$_2$ will start flowing out of this tube once the **LHe vessel** is pressurized. The LN$_2$ outflow should be transferred to a suitable container (e.g. a bucket).

5.9.6 Continue this process for about 5 minutes until it appears that no LN$_2$ is flowing out off the Teflon tube. Note that solid nitrogen has a very large heat capacity (an order of magnitude greater than copper), so even an inch left at the bottom of the vessel will require large amounts of liquid helium to cool to 4.2K.

5.9.7 Remove the **SS filling tube** from **LHe vessel** and seal the **helium fill port (C1)** by rubber stopper.

5.9.8 Close **ball valve 10**.

5.9.9 Check **temperature T1** and wait until it is higher than 82 K.

5.10 **PUMP/PURGE LHe VESSEL AND COOLING CIRCUIT**

5.10.1 Open **ball valve 1, 2, 3 and 4** on the control panel.

5.10.2 Open **ball valves 104** and **helium needle valve 105**.

5.10.3 Turn on **Turbo-pump (TP2)**, to evacuate **LHe vessel** and flow passage through the **needle valve, capillary tube** and **cooling circuit loops**, until the pressure drops below 0.1 torr (TC2) to remove any air or moisture.

5.10.4 Close **ball valves 104, 1, 2 and 4**, and turn off the **Turbo-pump (TP2)**.

5.10.5 Set **regulator valve 12** (on the gHe bottle) at 0.5~1 psig, and open **needle valve 11**, allowing helium gas into the **LHe vessel**.

5.10.6 After 30 seconds, close **ball valve 10** and **helium needle valve 105**. The **LHe vessel** is now pressurized (0.5~1 psig).

5.11 **LIQUID HELIUM FILLING TO LHe VESSEL**
5.11.1 Before LHe transfer, maintain the pressure inside LHe vessel at 0.5 psig by setting regulator valve 12 at 0.5 psig, and keeping valves 10, 11 and 13 open.

5.11.2 Unplug the rubber stopper on the helium fill port (C1), insert quickly the LHe transfer line to the bottom of LHe vessel through the helium fill port (C1) and tighten its connector. At the same time,

5.11.3 Close ball valve 16 on the LHe Dewar, and remove the plug of quick connector 14, open fill valve 15, insert slowly the LHe transfer line into LHe Dewar, until it reach the bottom of the LHe Dewar, and tighten quick connector 14.

5.11.4 Close ball valve 10 and open ball valve 22. The boil-off caused by the warm LHe transfer line being inserted into the LHe Dewar will cause immediate pressure rise and transfer liquid helium into LHe vessel.

5.11.5 Set the initial transfer rate of liquid helium at a very slow rate, by regulating the pressure in the LHe Dewar (in the range 0.5~1 psig). This guarantees that no liquid helium is accumulated in the LHe vessel until T3 at bottom of 4K-heat shield is cooled below 20K. This slow transfer makes more efficient use of the enthalpy of the liquid helium as it cools the LHe vessel and the attached radiation shield.

5.11.6 During LHe transfer, open and close helium needle valve 105 several times, to clear the path through needle valve and capillary tube and let liquid helium enter the cooling circuit loops for e-Bubble chamber cooling.

5.11.7 The venting flow rate can be monitored either by flow meter FM1 or FM2 on control panel.

5.11.8 When T3 at the bottom of the 4K-radiation heat shield has cooled down to approximately 20K, the helium transfer rate can be accelerated a little

5.11.9 Open helium needle valve 105 3~5 turns, and open ball valves 3 and 4 on the control panel, in this case helium vapor will vent out directly to atmosphere through check valve 12

5.11.10 Monitor temperature drops of T4, T5, T6, T7, T8 and T9 around the e-Bubble chamber. When the desired lower temperature has been reached, close ball valve 4 on the control panel

5.11.11 The venting flow rate can be monitored either by flow meter FM1 or FM2 on control panel.

5.11.12 Check the helium level meter occasionally. The LHe vessel is completely filled (21" on the level meter) using ~ 70 liters of liquid helium for cool down and fill.

5.11.13 It is important not to keep the helium level meter on except when you need to record the level to avoid the extra heat load to the LHe vessel.

5.12 AFTER LIQUID HELIUM FILLING

5.12.1 Upon completion of LHe transfer, temperature T3 at the bottom of 4K-radiation heat shield should stabilize at around 16K.

5.12.2 Open ball valve 16 and release the pressure inside LHe Dewar through relief valve R9 (0.5 psig), then lift slowly the LHe transfer line until it just clears fill valve 15, then close it. At the same time,

5.12.3 Lift slowly LHe transfer line from helium fill port (C1), and then seal it.
5.12.4 Close ball valve 22 at the helium vent port (C2), to prevent air from entering the LHe vessel. Helium vapor is only venting out through relief valves R4 (0.5 psig).

5.12.5 The pressure relief valve R4 is set at 0.5. This maintains a positive adjustable pressure inside the LHe vessel which prevents air entering the vessel, while maintaining a constant drive pressure to send LHe through the needle valve, and capillary tube into cooling circuit loops.

5.12.6 After the LHe transfer is complete, refill the LN2 vessel.

5.12.7 Be sure that the LHe transfer line is warmed up and dry before using again, by purging it with warm helium gas.

5.13 LIQUID HELIUM FILLING TO e-BUBBLE CHAMBER AND CENTRAL TUBE

5.13.1 By condensation with filling warm helium gas into EBC very slowly

5.13 DURING NORMAL OPERATION

5.13.1 Monitor temperature sensors for the holding time of the liquid helium and liquid nitrogen vessels. The normal boil-off rate of the combined total liquid helium volume (about 45 liters) is approximately 1 liter per hour, resulting in a hold time of about 2 days. The LN2 vessel has a net capacity of about 41 liters, and last more than 5 days. At end of LHe run out, the temperature of the 4K-heat shield will start to gradually increase above 20K, indicating that the heat load from the LHe vessel to the 4K-heat shield is slowly increasing.

5.14 LOWER TEMPERATURE OF E-BUBBLE CHAMBER

5.14.1 Adjust the needle valve operator 105 at the top flange of the cryostat to change the LN2 mass flow rate entering the cooling circuit loops from the LHe vessel.

5.14.2 Open helium needle valve 105 1~2 turns, and open ball valves 3 and 4 on the control panel, in this case helium vapor will vent out directly to atmosphere through check valve 12

5.14.3 Monitor temperature drops of T4, T5, T6, T7, T8 and T9 around the e-Bubble chamber. When the desired lower temperature has been reached, close ball 3 on the control panel

5.14.4 The venting flow rate can be monitored either by flow meter FM1 or FM2 on control panel.

5.14.5 Monitor temperature drops of T4, T5, T6, T7, T8 and T9 around the e-Bubble chamber.

5.15 SYSTEM WARM-UP

5.15.1 System warm-up consists of allowing the cryogen to boil away and the cryostat to warm to room temperature. There are two modes: one is normal warm-up and the other quick warm-up. If the system is left unattended for any length of time during warm-up, Caution signage and taping of the area should be in place beforehand.
5.15.2 Normal warm-up:
5.15.2.1 Use heaters placed at the top flange of the e-Bubble chamber to increase temperature and boil off LHe.
5.15.2.2 Wait for the liquid helium and nitrogen to boil-off and vent out of the pressure relief valves and vent ports.

5.15.3 Quick warm-up:
5.16.3.1 Open globe valve 13 and set regulator valve 12 at 0.5~1 psig. Connect the gas transfer line to the connector of vacuum valve 103 extending from the Cryostat.
5.16.3.2 Open needle valve 11 and purge the gas transfer line.
5.16.3.3 Open vacuum valve 103 and break the vacuum of the Cryostat vacuum jacket with warm helium gas from gHe bottle.

5.15.4 After the liquid helium has boiled away and the Cryostat has warmed up to room temperature, be sure that all ports are closed to prevent air from entering the vessel.

5.16 LIQUID WITHDRAWAL

This procedure will normally be used only under exceptional circumstances:

5.16. 1. Purge the LHe transfer line with gaseous helium.
5.16. 2. Insert the LHe transfer line to the bottom of the LHe vessel through helium fill port (C1), at the same time,
5.16. 3. Remove the plug of quick connector 14, open fill valve 15, insert slowly the LHe transfer line into LHe Dewar, until it reach the bottom of LHe Dewar, and tighten quick connector 14.
5.16. 4. Open vent valve 17 on the LHe Dewar. Liquid helium transfer from the LHe vessel will take place as the helium vapor inside the LHe vessel is vented from the vent valve 17.
5.16. 5. When the LHe transfer is complete, the temperature measured by temperature sensor T1 at the bottom of LHe vessel will increase abruptly.
5.16. 6. Wait a few minutes for helium boil-off to settle down, remove LHe transfer line until it just clears the fill valve 15, and then close the fill valve 15. Remove the line completely from the LHe Dewar.
5.16. 7. Close the vent valve 17, open ball valve 16 and let the LHe Dewar vent from ball valve 16.
5.16. 8. Install the plug of quick connector 14 and remove the LHe transfer line from helium fill port (C1).
5.16. 9. Seal helium fill port C1, close ball valve 22 on the helium vent port C2, to prevent air from entering the LHe vessel.

6. Documentation
6.1 EBC Log Book

7. **Attachments**

7.1 P&ID diagram
7.2 Flow diagram
Figure 7.1 P&ID diagram
Figure 7.2 Flow diagram