Istituto Nazionale di Fisica Nucleare

Laboratori Nazionali del Gran Sasso

DarkSide Project Process Procedure

Calibration Insertion System for DarkSide-50

Process Procedure Number: DS-OPER-9

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Procedure Author(s):

Brianne Hackett

Cary Kendziora

Erin Edkins

Jelena Maricic

Bernd Reinhold

Reviewed by:

Andrea Ianni (Site Manager)

Federico Gabriele (GLIMOS/RAE)

Augusto Goretti (Operation Manager)

Paolo Lombardi

Last Revised and Approved by:

Jelena Maricic

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1. Revision History

Revision #	Date	Author(s)	Rationale	Setion Update
1	May 30, 2014	BH	First Version	All
2	June 5, 2014	BH	Update	Introduction
3	September 13, 2014	BH	Update	Procedures
4	October 13, 2014	JM	Update	Procedures
5	October 15, 2014	JM	Update	Procedures

2. System Purpose

CALIS III (CALibration Insertion System III) is designed to deploy radioactive sources inside the neutron veto for the purpose of calibrating both the TPC and the neutron veto.
Specifically, CALIS III can deploy sources close to the cryostat wall of the TPC from top to bottom at different distances from the center line of the organ pipe, e.g. 15.87 inches (40.31 cm). The system is designed to deploy sources with a high level of precision. We expect the precision of the deployment to be better than 1 cm, based on the design and confirmed by the test campaign at FNAL conducted in the end of August 2014. The
system includes several safety features to ensure safe deployment and retrieval of the source without affecting the neutron veto detector. All materials that come in contact with the scintillator veto are made of stainless steel and Teflon except for the sealing O-rings which are made out of viton. All three materials (stainless steel, Teflon, and viton) are certified materials for contact with liquid scintillator (LS) in the neutron veto. Currently (as of October 2014) LS consists of PC (+PPO). It will be replaced in the near future with a mixture of PC+PPO with certain fraction of TMB.

CALIS III will be deployed into the neutron veto through one of the four organ pipes that connect CRH with the neutron veto. Once the device is vertically lowered into its specified location, an arm is raised to its horizontal position, by rotating the source arm around the pivot close to the bottom end of the device (pictures and detail mechanism explained later in the text), bringing the calibration source close to the cryostat wall. The calibration source is mounted at the tip of the arm and points directly toward the TPC.
Another feature of CALIS III is that the entire device can be rotated in the horizontal plane (azimuthal direction phi), moving the arm away from the cryostat, increasing the distance, and changing the position in the xy-plane. This rotation can be done while the gate valve is open and the source is next to the cryostat. In order to minimize outside contact with the LS, the entire apparatus is completely sealed during deployments and has been tested at Fermilab to be helium leak tight 8×10^{-9} std cc per second (helium).

3. Safety Hazards, Precautions and Equipment

3.1. Hazards for Personnel and Environment

There are two identified hazards for personnel and environment:
- hazard related to evaporation of the LS into the CRH either through:
  - leaks in the assembly
  - during source handling via viewport, in case of insufficient purging of the atmosphere inside the upper and lower assembly.
- hazard related to handling radioactive sources

3.2. Hazards to Experiment

Several hazards to the experiment have been identified.
- Contamination of the LSV with the radioactive source either by losing the source in the detector or by getting the source in contact with the LS.
- accidental mechanical contact with the PMTs.
- Contamination of the LSV liquid scintillator by radioactivity of dirty components or incompatible materials.
- Exposing the LS to humidity and oxygen.
- Exposing detector to light while PMTs are turned on.
- Losing the parts of the system in the detector.
- Inability to retract the system from the LSV

3.3. Safety Equipment and Precautions

CALIS III offers various safety features to ensure safe operations during calibration.

- Absolute encoder on the drive mechanism
  - The drive mechanism is a stepper motor that has an integrated absolute encoder providing the location of the source at all times, even in the event of a power failure.
- Servo motor torque limitations
  - The torque of the servo motor is strictly limited to the level needed for normal operation and it will stop in case of an unexpected load.
- Magnetic break
  - In the event of a power failure, the magnetic break ensures there is no movement of the PIG, avoiding any uncontrollable motion of the system.
- Speed reducer
  - The speed reducer (gears) is a double worm gear design. The primary worm gear has a 50:1 reduction and the secondary worm has a 82:1 reduction. The input speed of the servo motor is 2400 RPMs and the output is 0.6 RPM and has the weight capacity of 148 lbs. In the event of a power failure the speed reducer has the ability to hold the load at any position without back drive.
- The speed of the motor has been limited to average of 0.4 cm/s, which minimizes any lateral oscillation of the PIG during lowering and raising the source. Additionally, this is the maximum speed at which the motor can be operated without overheating.
- Manual retraction system
  - In case of complete motor failure while the source is deployed, it is possible to manually retract the PIG back to its home position and close the gate valve. The motor is disengaged, and wrench is used to manually wind the cable back on the spools and retract the PIG back above the gate valve. Detailed description of the manual retraction procedure is described in the Section 13.
- Cable strength and cable termination
  - The cables holding the PIG have been rated for loads over 590 kg, while the weight of the PIG is at the level of 10-15 kg so well below the breaking strength of the cable.
  - The cable terminations have been double crimped with stainless steel crimps and swivel hooks connected to the thimble of the cable termination.
- Cable length
  - The cable length has been established so that the maximum depth at which the PIG can be deployed is above the level of the light pulser of the PMTs. In case the command is given to deploy to greater depth, the cable completely unwinds and then rewinds in the opposite direction (going up) until the preset motor count of steps is reached (based on the correspondence between z position and motor step count).
- Upper limit switch
  - There is a limit switch inside the upper assembly that will cut the power to the motor if the PIG starts to move above its designated home position.
- Articulation retraction limit switch
  - Arm retraction limit switch cuts the power to the motor as soon as the arm is shifted from the vertical position. In this way, possibility of retracting the arm into the organ pipe while articulated has been eliminated.
- Choice of materials

  - All materials that come into contact with LS or their vapors, have been made out of stainless steel, teflon and viton that have been certified as safe in contact with the LS.
- Cleaning of CALIS III
  - Prior to installation inside the CRH, CALIS III is disassembled and cleaned in CR1, according to the DS established procedure to avoid any contamination.
- Light covers on the view ports
  - All viewports have very tightly fitting covers. Additionally, the main viewport cover will additionally be held in place with clamps to avoid any possibility of accidentally exposing the LSV to excessive amount of light.
- Leak tightness of the source
  - The source is placed inside a stainless steel container that has an o-ring seal (made out of viton) during calibration. The container has been tested at Fermilab to be helium leak tight at the level of $8x10^{-9}$ std cc per second (helium).
- Securing of the source
  - All connection points for the source and arm have been secured with two short push locking pins that cannot be disengaged without a person pressing the pin. Due to difference source sizes, two source holders, identical in design, but different in size have been fabricated. Both source holders have been helium leak tested to be fully gas tight. The source holder is held in place via a locking mechanism and two locking pins (see Fig 1 and Fig. 2). When the source is attached to the arm, the source container must be slid over a protruding pin. There is a sliding locking mechanism that interlocks onto the pin. Once the source is locked into position there are 2 additional locking pins that are put into place (one above and one below the source holder pin), each of which have a button that must be depressed in order for the pins to be released. See DocDB #858 for two movies in which this mechanism is demonstrated. In addition, the source holder and the 2 locking pins will all be tethered from outside the view port until they are locked in place eliminating the possibility of accidental falling. The tethering will happen before installation of the source and before the removal of the source. The cables used to tether the pins and the source holder during installation and removal will be detached after installation and prior to deployment to avoid the possibility of the arm getting entangled.

Figure 1: Locking mechanism for the source holder. This photo shows two push pins that ensure that the sliding pin stays in place and the the source holder cannot under any cir- circumstances get detached from the arm. The only way to remove the push pins is to depress buttons on each of them by hand.

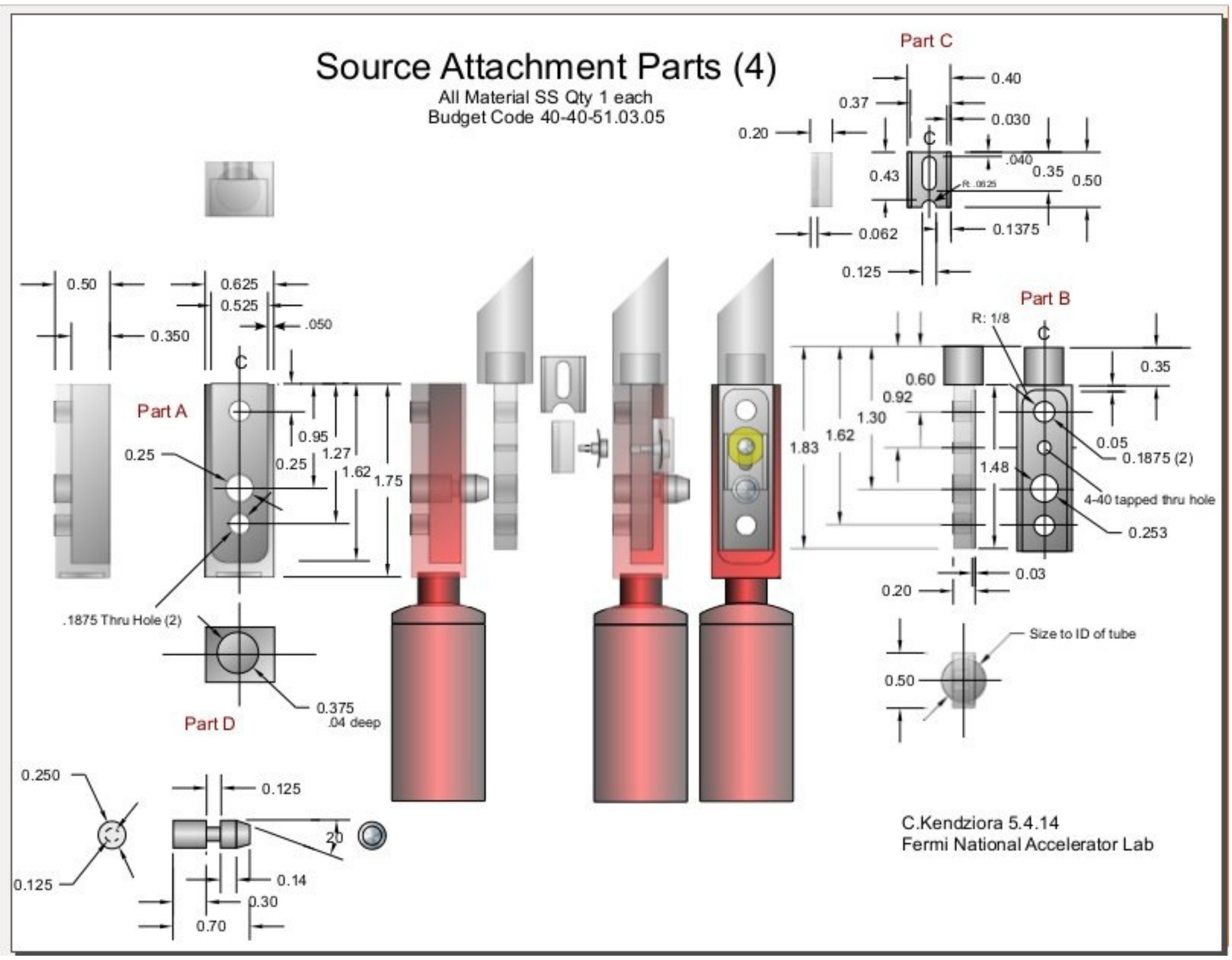

Figure 2: Components of the source attachment mechanism. Central image shows how the pin that holds the source holder slides down and prevents the source from getting loose. The slide pin is locked in place by two push pins shown in Fig. 1 the veto.

- Contamination of detector with oxygen and water
  - o In order to avoid contamination of the detector liquids with oxygen and water, vacuum and nitrogen pressurization systems have been developed. The oxygen content must be below 20 ppm for opening the gate valve. Any level beyond 20 ppm may affect the LS. The oxygen monitor is not present to check if the level is below 20 ppm, so the following method will be applied to ensure below 20 ppm oxygen content:

    20.pm is a reduction factor 10000 with respect to the atmospheric air. If we pump the vacuum from 1000 mbar to 100 mbar and we brake the vacuum with nitrogen, repeating the procedure 4 times, we will reach the required reduction factor (we will add 2 or 3 more cycles as a safety margin).
- Detailed nitrogen and vacuum systems descriptions and operational procedures are documented in section 11.4 and section 11.3.
- Health hazard from LS fumes for people and environment CALIS III has been tested to be leak free with a helium leak test. Once the gate valve is closed and prior to any manipulation of the source through viewport, CALIS III will be thoroughly flushed with N2 to avoid any health hazard.
- Light Tightness
  - o In order for CALIS III to be light tight, all view ports have light tight covers for when the organ pipe gate valve is open. When any view port or access port is opened, the gate valve must be closed, eliminating the possibility of leaking light into the veto.

Additionally, all seals of CALIS III have been tested for leaks and confirmed to be helium leak tight. The gas tightness will be validated again after installation on the gate valve with gate valve closed. During the commissioning phase light tightness will be tested. Details of the light tightness procedure are described in section 11.9.

4. Responsibilities

4.1. Calibration Director

Person: Bernd Reinhold

The Calibration Director is responsible for ensuring the safe execution of this procedure. Any problems encountered by the Calibration System Operators should be relayed to he/she as soon as possible. The Calibration System Operators shall confirm with the Calibration Director as well as the Operations Manager before operating the gate valve. The Calibration Director may wish to administer a verbal test of the Operator's knowledge of the emergency procedures.

4.2. Calibration System Operators

Persons: Brianne Hackett, Bernd Reinhold, Cary Kendziora, Erin Edkins, Yura Suvorov, Jelena Maricic

Operators perform the start up of the calibration system, source insertion, positioning, source removal, and system shut down. They are required to report any problems or questions to the Calibration Director, and must communicate any problem to GLIMOS, Site Manager and Operation Manager before calling the guards and firemen. If there are problems related to spills or safety issues, the GLIMOS must be informed. One of the operators must contact the Calibration Director and Operations Manager before operating the gate valve. They must be in very close communication with the LSV DAQ manager and DAQ shift leader during the opening of the gate valve to monitor any increase in the PMT rates which might indicate a light leak. If a source needs to touch the outer vessel of the cryostat for any reason, the Calibration System Operators must first consult with the cryostat expert. The system can be safely operated with one of the above people, and one other adequately trained person.

4.3. Operations Manager

Person: Augusto Goretti

The Operations Manager is responsible for the safe and proper functioning of the DarkSide equipment. Calibration System Operators must have his/her permission before operating the gate valve. He or she should be on call throughout the entire operation.

4.4. DAQ Shift Leader

Person: Bernd Reinhold, shifter for the TPC DAQ
Person: Stefano Davini for the veto DAQ.

The DAQ shift leader is responsible for the proper functioning of the DAQ system for DarkSide. When the Calibration System Operators are first opening the gate valve, the DAQ Shift Leader must carefully monitor the PMT signal rates, any deviation from the accepted values should be relayed to the Calibration System Operators; the DAQ Shift Leader should be prepared to terminate the HV to the PMTs in the event that the signal rate rises unacceptably high.

Veto DAQ expert presence is mandatory during the light leak testing as part of CALIS III commissioning.

4.5. TPC and Cryostat Vessels Expert

Person: Peter Meyers

The vessels expert should be on call throughout the entire operation in the event that the source needs to come into contact with the cryostat itself.

4.6. Shift Leader

Persons: Brianne Hackett, Erin Edkins and Bernd Reinhold

The shift leader is responsible for monitoring the status of the detector during a calibration campaign. In the event that the calibration campaign spans several shifts, an overlap period should be scheduled between shift leaders so that they can be adequately informed of the current status.

5. Insertion System Hardware

5.1. Description

The overall device consists of three main assemblies: the lower assembly, upper assembly, and the source deployment mechanism. Fig 3 shows the layout of the system as installed in CRH and deployed in the Liquid Scintillator Veto (LSV). Fig. 4 shows the details of the full device with all dimensions included.

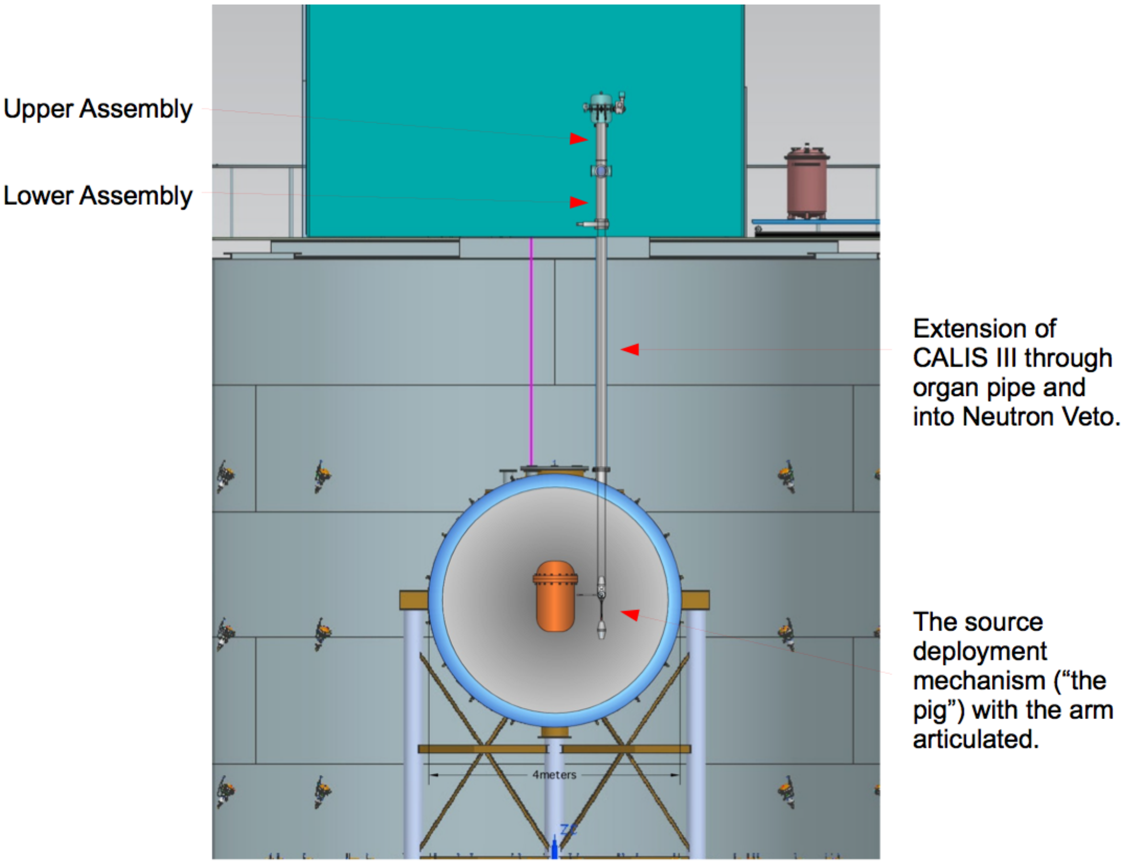

Figure 3: A conceptual drawing of CALIS III installed in CRH and deployed in LSV next to the cryostat. The CALIS III extends into the LSV during calibration only. The z position is controlled via the stepper motor located in the upper

assembly. Raising of the source arm (shown in both vertical and articulated, horizontal position) is achieved by manual raising of the cable for a fixed length. Azimuthal rotation of the source is achieved by rotating the upper assembly and the source deployment mechanism with respect to the lower assembly. This can be done during deployments as the system holds pressure during the entire process. CALIS III is parked inside the upper and lower assemblies when not used for calibration. The gate valve at the top of the organ pipe remains closed except during calibration campaigns.

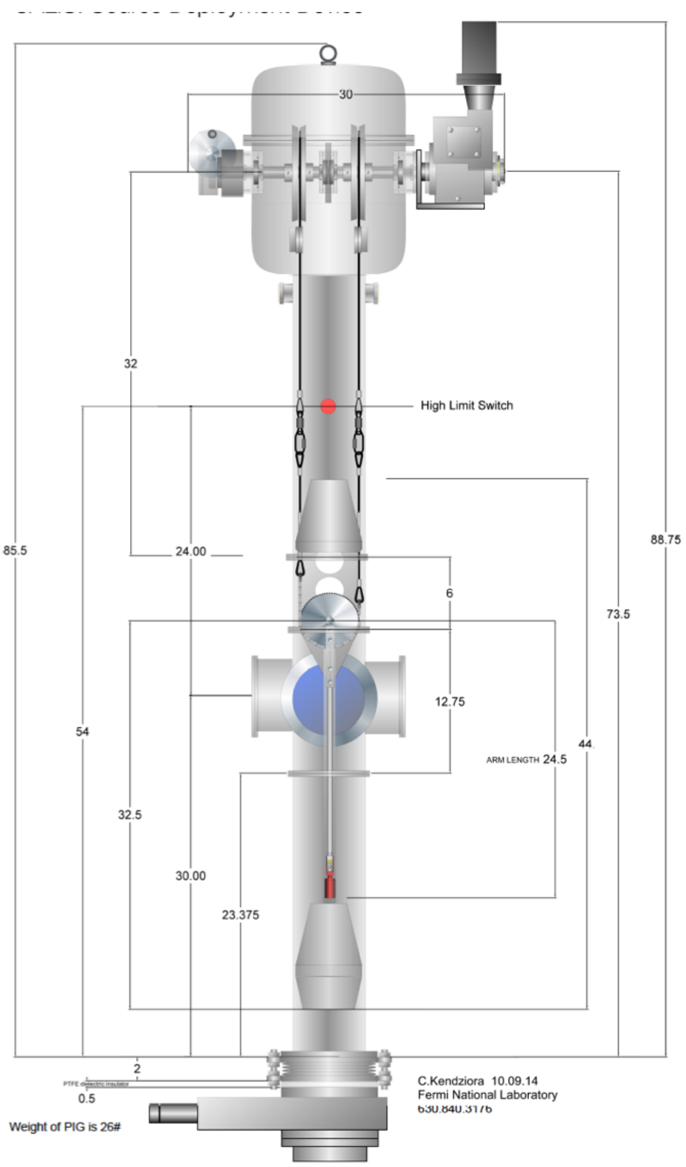

Figure 4: Mechanical drawing of the full device with dimensions in inches (centimeters) shown. The arm length is variable, the 40.31 cm (15.87 inch) long arm is shown in the figure.

The lower assembly (Section 5.2) is attached to the top of the gate valve (that closes the organ pipe in CRH), visible at the bottom of the Fig.4 and protruding to the left. On the top of the lower assembly is a view port (depicted in blue) and an access point for accessing the arm and exchanging sources. The structure shaped like two joint cones below the viewport guides the system smoothly down the organ pipe. The source capsule is visible inside the blue viewport. The circular gear above the viewport allows the rotation of the source arm to horizontal position as shown. The second conical cap above the rotation gear mechanism contains a cylindrical weight to minimize any lateral motion or oscillations during deployment and articulation and dearticulation especially. It also ensures smooth motion of the CALIS III into the organ pipe and back to the top park position. Fig. 5 shows the photo of these parts as assembled. Inside the upper assembly (Section 5.3) that attaches to the lower assembly are the two spools (shown in profile) used to wind and unwind two cables that hold the deployment mechanism simultaneously. The spools are attached to a single shaft rotated by the stepper motor drive shown at the top right side of the upper assembly. The small circular object located at the top left of the upper assembly is the manual handle for source arm articulation to horizontal position and back to vertical position during deployments. The drive mechanism is controlled via a LabVIEW interface (Section 7.1). The third assembly of the device that contains the source deployment mechanism is called "the PIG", Section 5.4. It encompasses the arm, the source container (located at the end of the arm), and two conical shells (mentioned above) for the smooth transportation of the source (again see Fig 5 for details). The PIG is stored in the upper assembly, with the source arm in view, through the view port of the lower assembly. This allows the gate valve to remain closed except during calibration of the detector. During deployments the whole PIG is lowered into the detector.

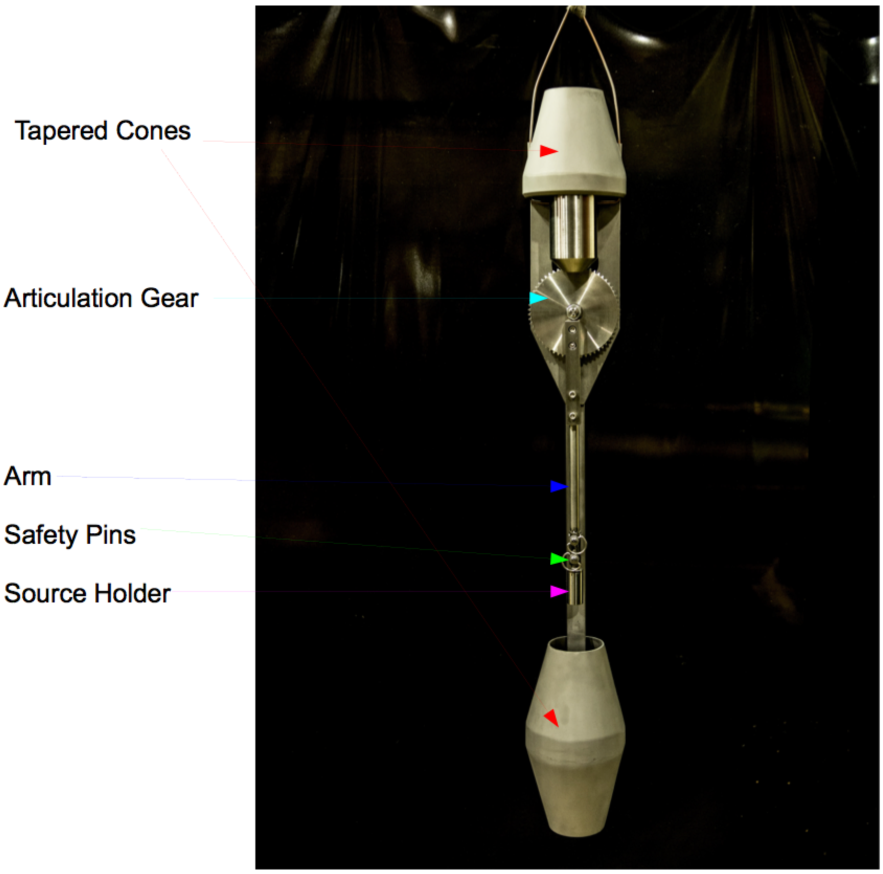

Figure 5: The PIG-support for the arm and the source holder.

5.2 The Lower Assembly

The lower assembly is a cylindrical stainless steel enclosure pipe that contains the ports for viewing and accessing the source and the cables on its upper end. The front view/access port can be opened for easy manipulation/ handling of the source. Below the
view port is a sealed connection that has an O-ring seal and uses a ring clamp to compress the seal. The clamp can be slightly loosened to allow the entire

upper assembly with the PIG to be rotated with respect to the lower assembly and the detector. Refer to Fig. 6 for a conceptual description of the device rotation with respect to the detector and the assemblies). The angle rotation is read out from the measuring strip. The ring clamp and the measuring strip are shown in Fig. 7. During the rotation in the xy-plane, light and air tightness are preserved. Thus, the rotation of the PIG can be performed, while the PIG is deployed next to the cryostat (and open gate valve). The lower assembly is connected to the gate valve on top of the organ pipe in CRH. The distance from the center of the viewing port to the top of the gate valve angle is 74.85 cm (29.47 inches). This distance was based on a person sitting comfortably in a chair while handling the source. Fig. 8 shows the dimensions of the lower assembly and the upper and lower assemblies connected as they will be in CRH in comparison to a person of average height. When the source arm is centered in the view port, the view port may be opened for handling of the source. This is considered the home position for the PIG.

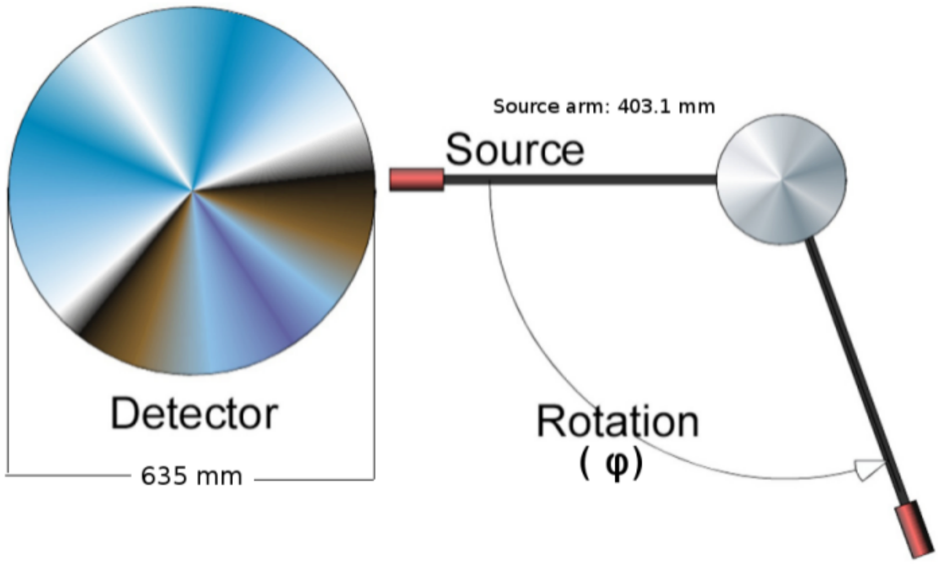

Figure 6: Shows the top view of the upper assembly and how the azimuthal rotation of the source is achieved by rotating the whole upper assembly with respect to the lower assembly and the entire detector.

Figure 7: Ring clamp with the angle measuring strip shown below. In order to perform azimuthal rotation, ring clamp is slightly loosened, and the entire upper assembly is rotated with respect to the lower assembly, along with the PIG. The angle of rotation is read out from the strip that goes around the pipe.

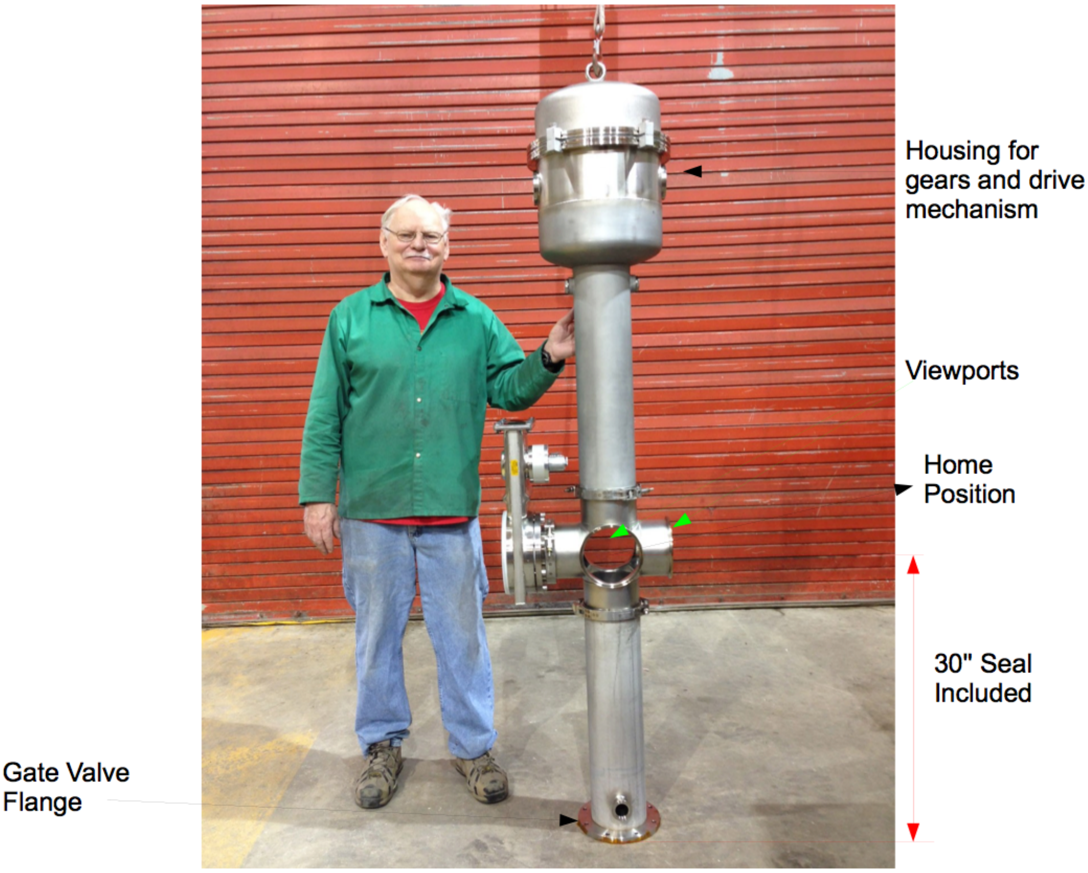

Figure 8: Shows the upper and lower assemblies together as they will be installed in CRH next to a welder for perspective. An additional 20 cm (8 inch) long pipe section has been added above the viewport to accommodate longer arms inside the upper assembly.

5.3 The Upper Assembly

The upper assembly is a stainless steel cylindrical enclosure that houses the drive mechanism and the gear drive for the cables. The raising and lowering of the source is controlled by a servo motor drive which is operated via a LabVIEW interface (Sec. 7.1).

The motor controls the z positioning of the source by simultaneously unwinding and winding a pair of cables that the PIG is attached to. We are able to specify in LabVIEW a z position that we want the source to be in and command it to go there. In order to move up or down in z, the motor is given a certain number of steps to go. There is a translation table that gives correspondence between each z position and the number of steps on the motor. The motor has an absolute encoder and step position is never lost even in the case when the motor loses power. When the PIG has reached its home position within the upper assembly it will stop. However, if the top of the PIG continues past its home position (based on the number of steps given), it will not be able to pass its home position thanks to the upper limit switch that will be triggered in that case. When contact is made with the switch, it will trip the upper limit and open the circuit, turning off the 24 Volts line powering the motor. This would be considered a system failure and the problem will need to be understood and corrected before continuing. Fig. 9 shows the schematic of the connection between the limit switch and the motor.

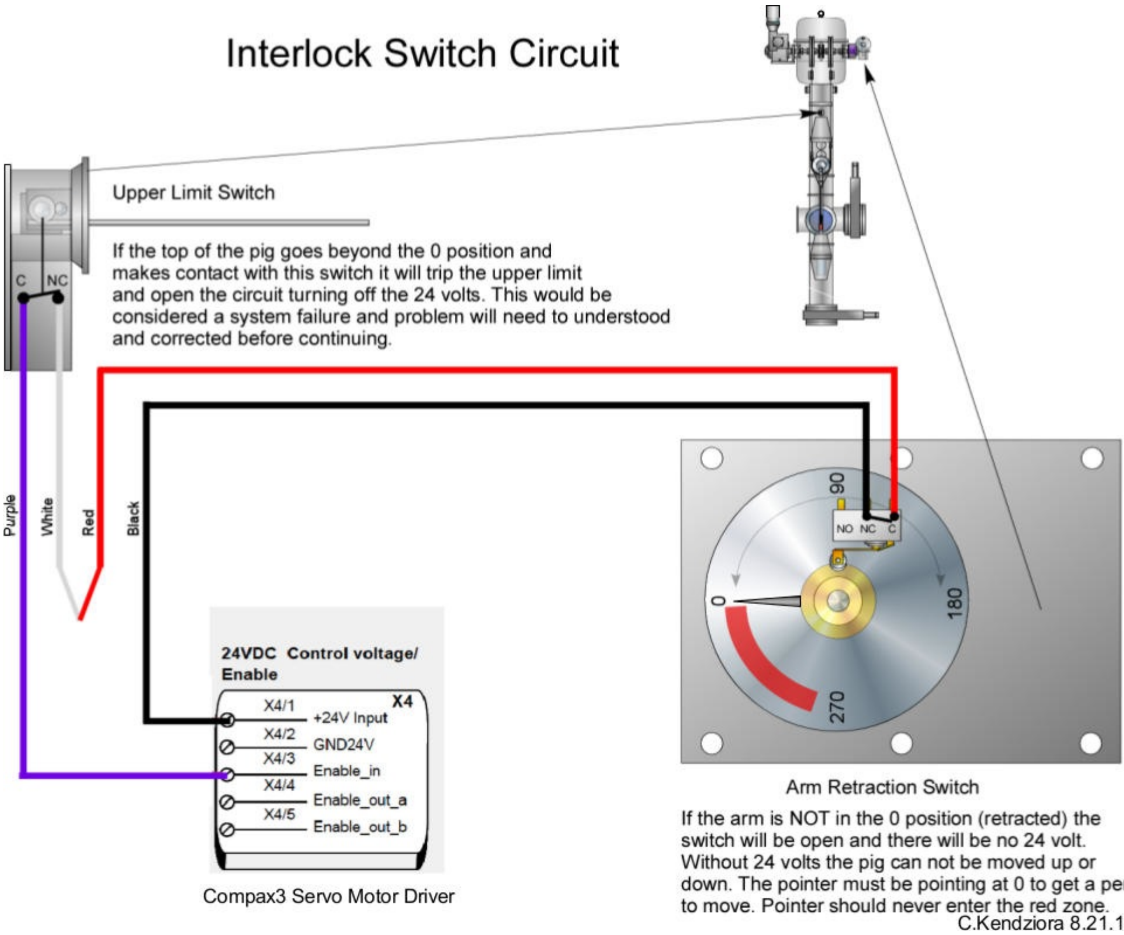

Figure 9: The schematics of the upper limit switch and the arm retraction switch. The former prevents the PIG from moving above the home position of the PIG, while the latter prevents any motion of the motor when the arm being articulated to prevent any possibility of articulated arm being retracted inside the organ pipe. In both cases, operation of the motor is prevented by cutting power to its 24 Volt line. The arm articulation switch allows the motor to be

powered only when the dial is pointing toward zero, which corresponds to the arm being vertical (de-articulated).

The articulation of the arm is operated manually. A hand wheel located outside of the device (shown in Fig. 10 on the left side) allows the user to manually raise the arm to its horizontal position. Section 5.4 details the use of the hand wheel to articulate the arm. To prevent the system from being moved while the arm is articulated, an arm retraction switch has been installed. If the arm is not in the vertical position, the switch will be open and there will be no power to the motor (no power in the 24 Volt line), as can be seen in Fig. 9. Without the 24 Volts, the PIG cannot be moved up or down. Fig. 10 is an image of
the upper assembly inner components with the hand wheel on the left side and the servo motor on the right. Fig.11 provides a side view of the upper assembly inner components.

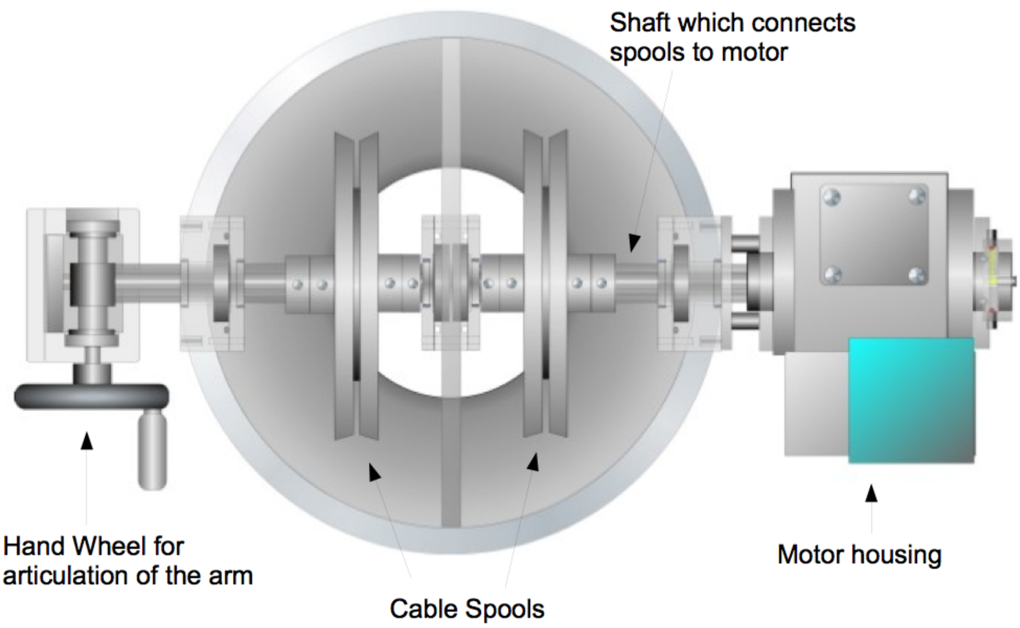

Figure 10: Looking down on the top of CALIS III and inside the upper assembly: the components and drive mechanism are shown. The hand wheel is on the left connected to one of the spools only. The next parts going from left to right are the two cable spools and then the sealed motor housing.

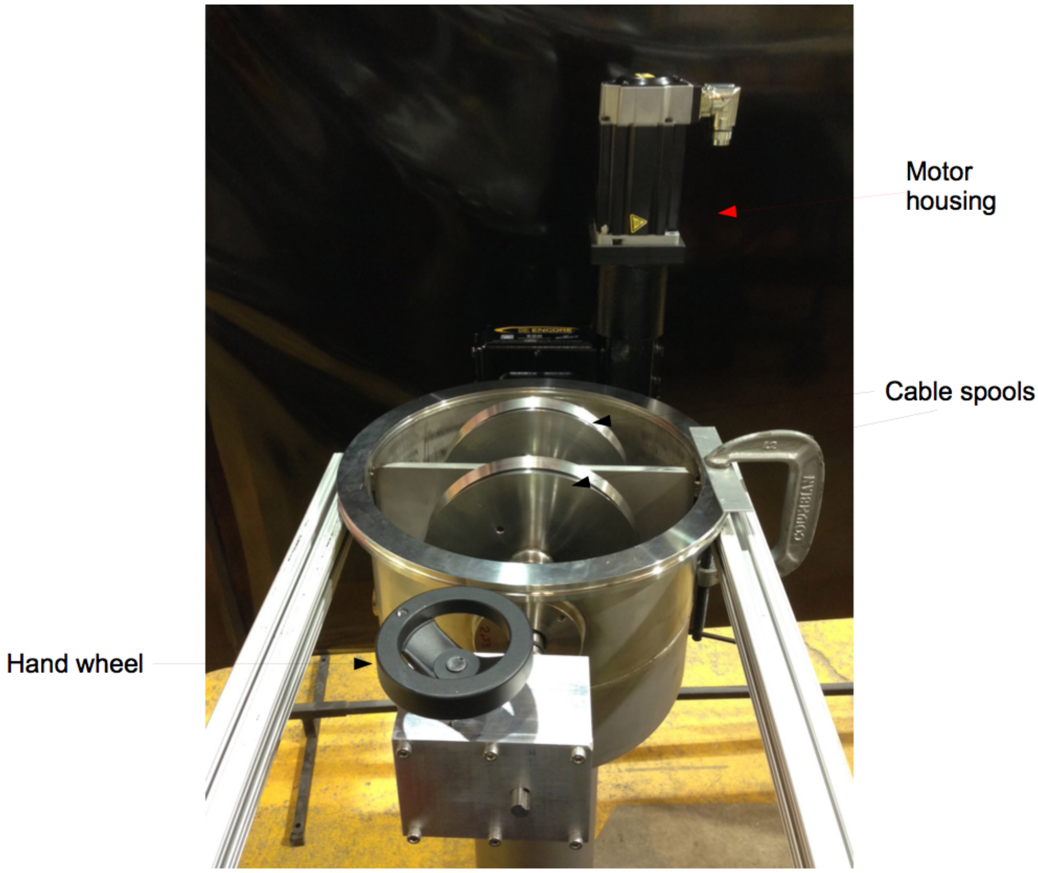

Figure 11: The photo of the hand wheel and top of the upper assembly. The two cable spools are visible inside.

Figure 12: The photo of the PIG with the arm in its horizontal position.

5.4 The PIG

The PIG (Fig. 5) contains the support structure for the arm which holds the source at its end. This piece is equipped with tapered cones on the top and bottom that ensure that the ends do not get snagged on inner edges of the organ pipe as it is moving up and down.
It is attached to the assembly by the two cables. Swivel hooks are employed in the attachment of the cables to the PIG that allow the cables to move freely and not get tangled. There is a chain that goes from the swivel hook around the gear to the second swivel hook. In the center of the gear is a custom designed and fabricated source arm pivot that the arm is attached to and that rotates together with the articulation gear visible in the center of the PIG. See Fig. 12 for an image of the arm raised to its horizontal position.

For articulation, there is currently a choice of several arm lengths from 40.31 cm up to 62 cm. Each of these lengths are measured from the center line of the organ pipe to the end of the source holder. The arm lengths, 57.15 cm and 62 cm are intentionally made too long as they will be used to determine the exact location of the cryostat; some uncertainty in the cryostat's z and lateral position exist at the level of 3 – 4 cm. The organ pipe we intend to use is 81 cm distant from the cryostat center (and the geometric center of the LSV sphere) as measured from the centerline of the organ pipe. The cryostat is 32 cm in radius, which leaves a distance of around 49 cm to be reached by the arm. The articulation of the arm is operated via a hand wheel located on the side of the upper assembly close to the top. By rotating the hand wheel, one of the cable spools inside the upper assembly will rotate, pulling up on one of the cables attached to the PIG and shortening it for the length equal to the one quarter of the gear circumference (which is 10 cm). As a result, the chain at the bottom of the cables engages the articulation gear (see Fig. 5 for an image of the articulation gear) on the PIG and raises the arm to horizontal. The chain has a guardrail that ensures that the chain can never come of the gear. Thus, in the process of articulation the entire PIG along with the source arm shifts up for 10 cm. See Fig. 13 and Fig. 14 for a closer look at how CALIS III articulates the arm. In order to determine the degree of articulation of the arm, a protractor is placed next to the hand wheel. This protractor and the hand wheel are calibrated together for an accurate reading of the articulation. The reading of the protractor dial is different at different heights and the calibration table obtained from the tests is used to determine the dial setting necessary to articulate the arm to the horizontal position. We have adopted a spherical coordinate system for the rotation of the system and the articulation. Articulation of the arm is measured from the z-axis; when the arm is fully articulated, it is at 90° and when it is in its vertical position it is at 180°. As mentioned in Sec. 5.2, the rotation of CALIS III is done in the xy-plane which corresponds to the azimuthal direction, a rotation in φ. See Fig. 15 for details.

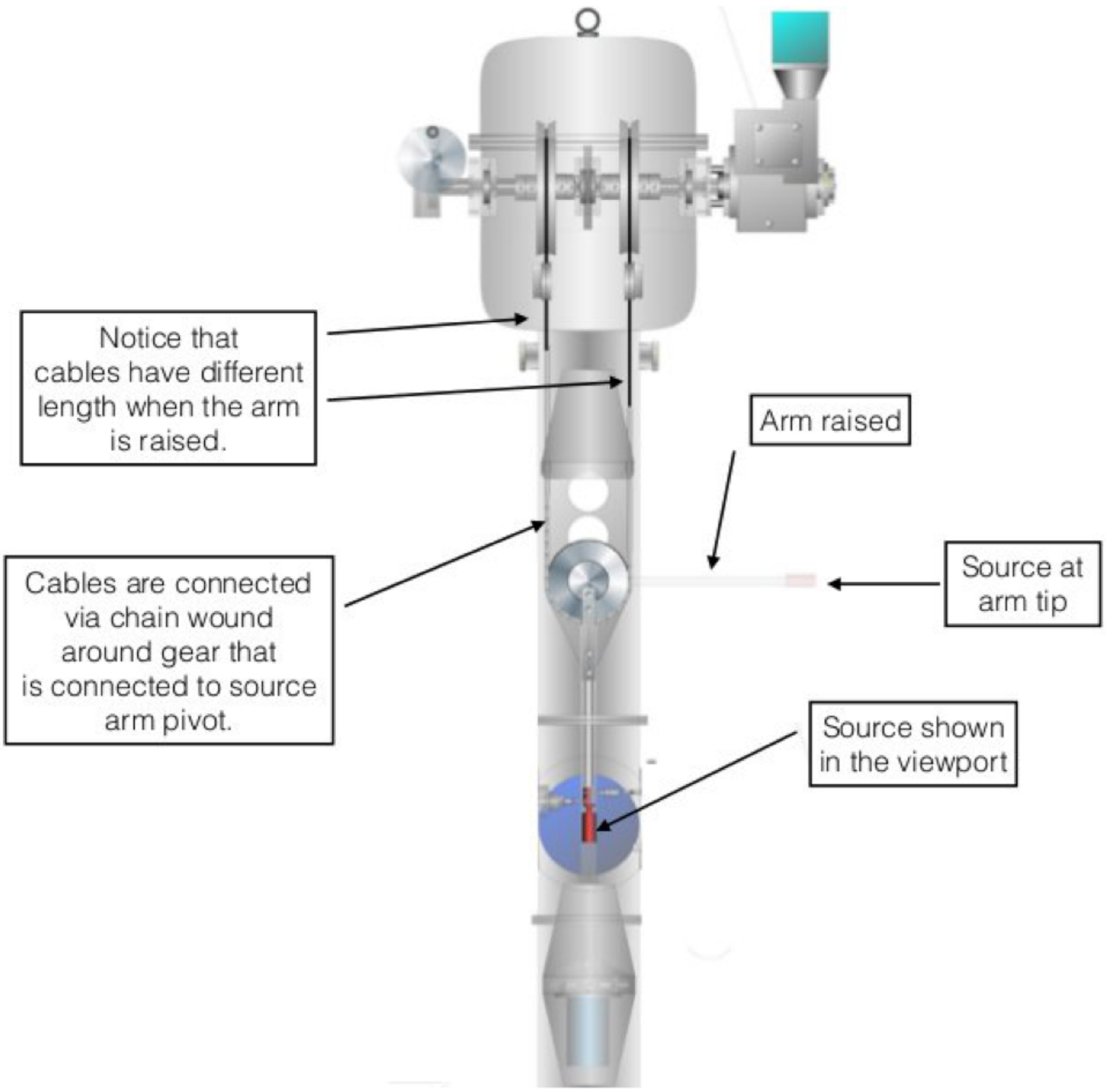

Figure 13: CALIS III showing the inner workings of the articulation of the arm and the arm in its vertical position.

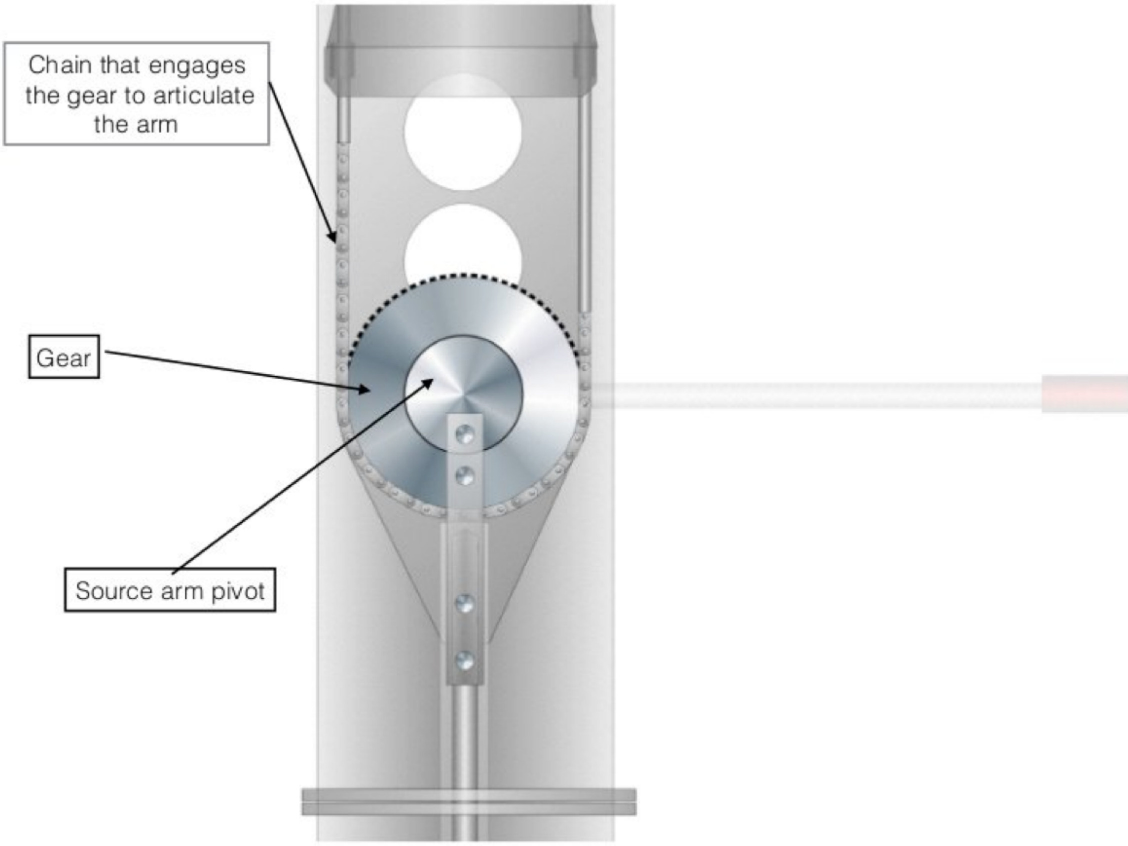

Figure 14: Technical drawing showing the mechanism behind the rotation of the arm.

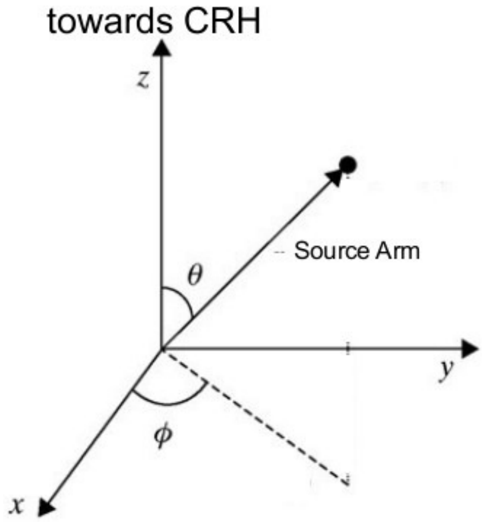

Figure 15: Spherical coordinate system used for establishing the direction of the rotation of CALIS III and the articulation of the source arm. θ is kept at 90 degrees when arm is articulated, and at 180 degrees when dearticulated. x-axis is the direction toward the center of the detector.

6. Gas Flow System

One of the most important features of this system is making sure that the LS residue on the device are extracted from CALIS III prior to opening access ports to exchange the source or arms. This is important to maintain a safe working level for the people involved and for the detector. This can be addressed through a system evacuation and nitrogen purge. To accelerate the removal of the LS residue that is left after a deployment, CALIS III will undergo an evacuation with a vacuum pump. By lowering the pressure inside of CALIS III below the vapor pressure of the LS (currently the vapor pressure of PC +PPO and later on, once TMB is introduced the vapor pressure of PC+PPO+TMB), it will cause the LS to outgas and be removed through the vent line of the vacuum pump. An additional step to remove the LS is to purge using N2. We will need to limit the potential flow rate of the nitrogen to ensure that an ODH (Oxygen Deficiency Hazard) condition is avoided in CRH. Only once this is accomplished will the view port be allowed to remain opened and the source handled.

The entire CALIS III has been tested at FNAL to hold pressure and is completely gas tight. The system will be tested again after installation on the gate valve as part of the commissioning procedure described below. CALIS III uses the vacuum and N2 system shown in Fig. 16 to purge all oxygen and humidity out of CALIS III prior to getting in contact with LSV. These systems are leak checked to have a leak rate of less than 1 $x10^{-7}$ and pressure tested to 200 mbar.

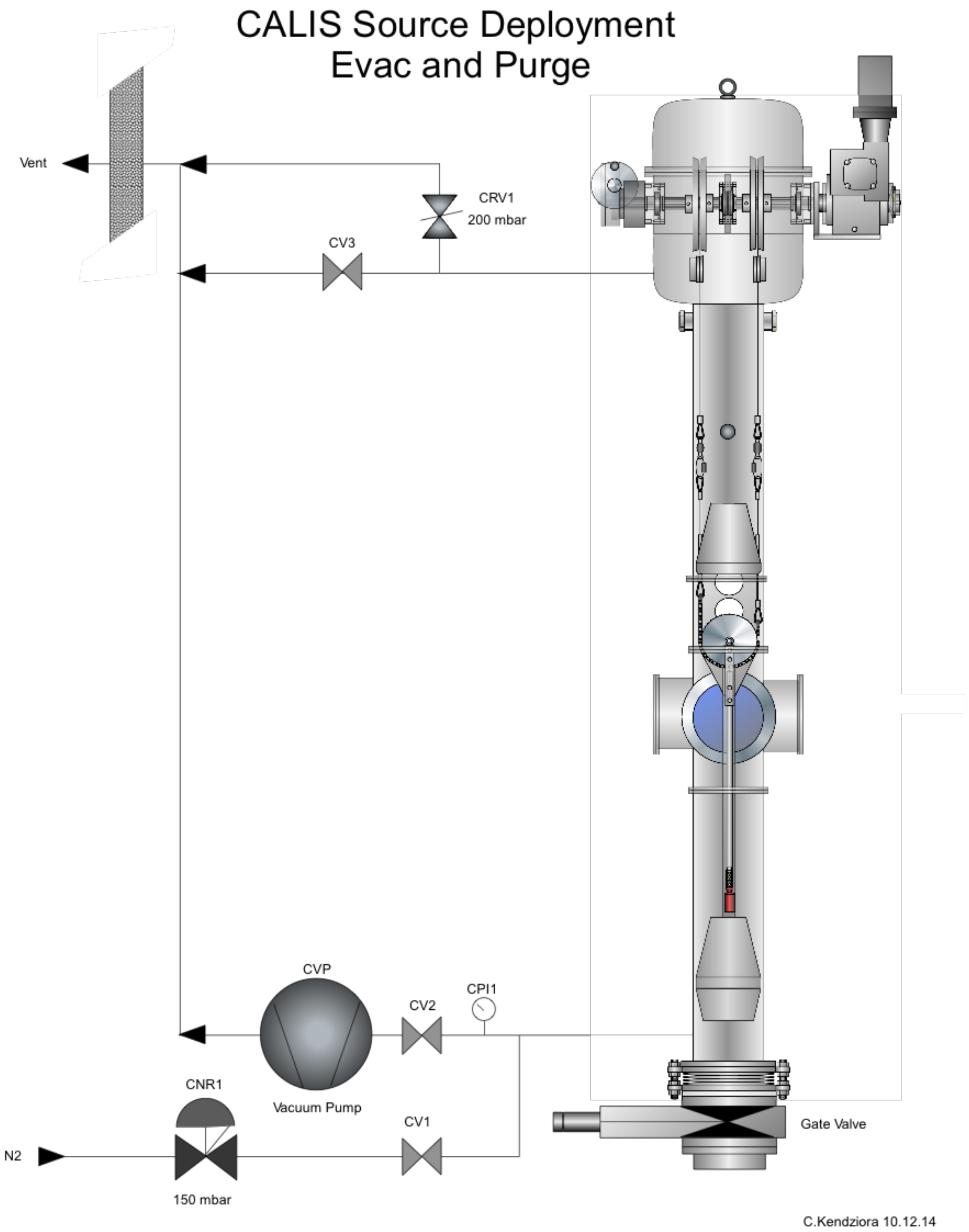

Figure 16: The layout of the nitrogen and vacuum system of CALIS III.

7. Software

7.1. LabVIEW Interface

Graphical user interface (GUI) to the stepper motor is realized with the LabVIEW, graphical programming language. The program communicates with the drive mechanism and the absolute encoder. The vertical movement of the PIG is controlled via LabView. The interface gives the z-position of the PIG according to the absolute encoder, hereafter called the step position. Step position 0 is the home position of the PIG. Starting and stopping of the PIG is controlled in this interface. LabVIEW also shows a plot of the motor current vs time as the PIG is moving. In order to command the PIG to move, the desired step position is typed in, followed by a click on the Start Move button. If, at any time in the movement of the PIG, you wish to stop the PIG before it reaches the set step position, then click the Stop Move button. The photo of the current GUI is shown in the Fig. 17.

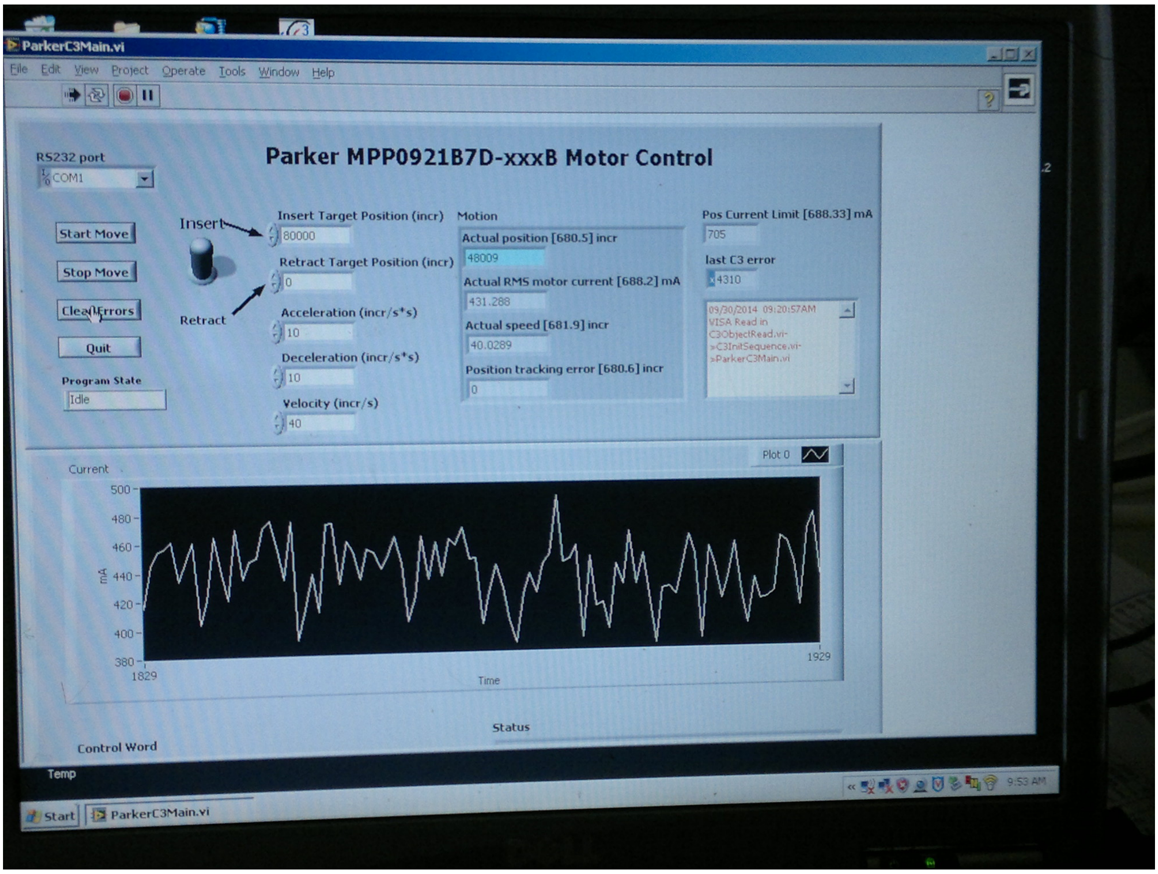

Figure 17: The photo of the GUI used to control the motor.

8. Calibration System Prerequisites

8.1. Cleaning

Prior to installation in CRH, CALIS III has been cleaned as per the procedures laid out in BX-CLEAN-02-05-R2 in CR1. The entire system has been disassembled and each component has been cleaned in the ultrasonic bath according to the prescribed procedures. After cleaning and drying, components were taken into CRH and clean assembled there.

8.2 Systems Check

There are two types of system checks. The first system check is performed during the final commissioning of CALIS III in CRH. The goal of the commissioning system check is to verify that CALIS III is performing properly after clean assembly. Detailed steps of the commissioning are described in the procedures section.

The second type of system check is performed before any calibration campaign or any operation related to CALIS III and is described in the normal calibration operations procedures section.

9. Personnel Prerequisites

The personnel performing the source insertion operation (the Calibration System Operators) have been adequately trained to perform the tasks required of them in a manner that is safe for personnel and equipment. In particular, these individuals have knowledge of normal operating procedures, system startup and shutdown procedures, and emergency shutdown procedures. The schedules and shifts have been planned, and the personnel on shift during the insertion process have been trained for the tasks they must perform during the calibration operation and made aware of their responsibilities. Additionally, all personnel that will be on call have been notified and their telephone numbers and calling sequence have been established and posted in CRH and the control room.

10. Site Prerequisites

1. Essential services in Hall C are expected to continue through the calibration period (electricity, air ventilation, shuttle transportation).
2. Inform the LNGS PPS before the operation (it is not necessary inform the director).
3. The PPS (if he/she requests such notification) and people responsible for the services must be informed that the calibration for DarkSide-50 will start, and in particular, that the gate valve will be opened. The PPS should also receive the planned procedures.
4. All necessary safety systems are in working order.
5. Firemen have been informed that the gate valve will be open and that calibration campaign will take place.

11. Commissioning and installation of CALIS III procedures

CALIS III will be installed on the top of one of the four gate valves located on top of organ pipes that connect CRH with the LSV. The Fig. 18 shows the location of the gate valve that we have selected for CALIS III installation. After CALIS III is installed on top of the gate valve, there will be a series of tests to validate that CALIS III is safe for use in the LSV and that it is properly installed and functioning. These tests, (described in detail in the following text) are:

1. vacuum evacuation (PMT HV OFF)
2. nitrogen purging and pressurization (PMT HV OFF)
3. pressure stability after opening the gate valve (PMT HV OFF)
4. vertical deployment with a source holder, but no source inside (PMT HV OFF)
5. deployment in the LSV with articulation (PMT HV OFF)
6. electric contact test to determine position of the outer vessel of the cryostat with respect to CALIS III (PMT HV OFF)
7. light tightness test that includes slow ramping of the PMT HV

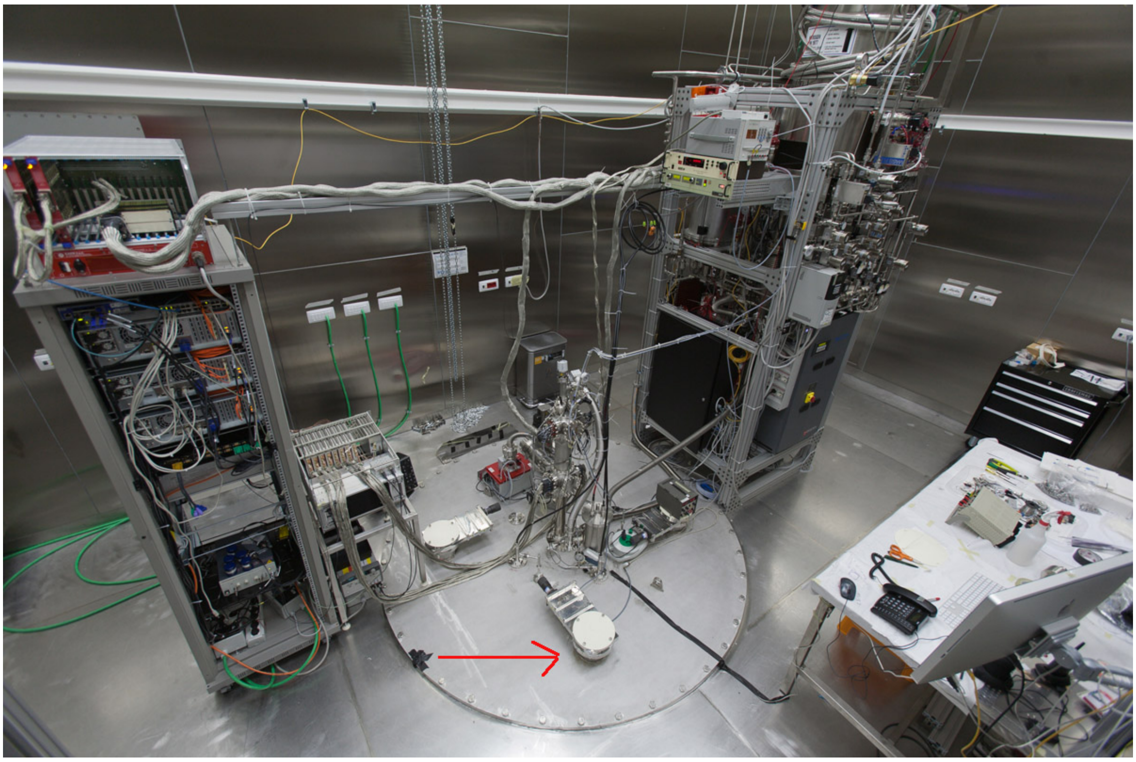

Figure 18: The red arrow indicates the proposed location for installation of CALIS III within CRH. This is organ pipe N11C.

11.1 Validation tests after clean assembly in CRH and prior to installation on the gate valve

CALIS III will be brought to CRH as bagged cleaned pieces and the sub assembly will begin. The upper section will be placed under the crane near the wall opposite to the cryogenic system and raised. The other sections will be attached to the upper section using the crane. Once the entire assembly has been completed, CALIS III will undergo basic set of tests.

1. The servo motor drive will be tested by raising and lowering the pig using the height available in CRH. (The calibration of the cables at full length and the home position will take place after the cables are fully unwound. They are presently at an unknown tension.)

2. The smoothness of the cable winding and unwinding will be verified to test any stickiness of cleaned cables. No issue is expected.

3. Articulation of the arm will be tested to work as expected. Arm will be rotated slowly using hand wheel.

4. The limit switches will be tested to make sure that they will stop the motor drive if actuated.

11.2 CALIS III installation procedures

Once the software and hardware satisfactory performance is confirmed (which should take around one day), CALIS III will be mounted on the gate valve using a crane. A Teflon disk (1.25 cm thick) will be placed between CALIS III and the gate valve for electrical insulation of the system from the rest of the CRH.

Once CALIS III is mounted to the gate valve the system will be helium leak checked. If no leaks are found, the N2 and vacuum system will be attached as in Fig.19. These systems will be leak checked to have a leak rate of less than $1x10^{-7}$ and pressure tested to 200 mbar. Once all the leak tests have been completed and no leaks are found, the commissioning of CALIS III will begin. Each of the described tests is conducted as a separate test as the tests may require longer than a day to complete.

11.3 CALIS III commissioning: Vacuum evacuation procedure

CALIS III uses the vacuum and N2 system shown in Fig. 16 to purge all oxygen and humidity out of the system assembly prior to getting in contact with the LS. These systems are leak checked to have a leak rate of less than $1x10^{-7}$ and pressure tested to 200 mbar.

The first step in CALIS III commissioning will be to evacuate the system to full vacuum:

1. Close valves CR1 and CR3 (shown in the schematics).

2. Open valve CR2 with the vacuum pump running until the pressure is reduces to a full vacuum.

11.4 CALIS III commissioning: Nitrogen flushing and pressurization procedure

Vacuum evacuation of the system is followed by nitrogen flushing and pressurization. This process includes the following steps.

1. Backfill the system with N2 by closing the valve CRV2.

2. Open the valve CR1.

3. Increase the pressure to 150 mbar.

4. Make sure the pressure can go below the water vapor pressure at the CRH temp (to be sure that there is no humidity left).

5. Evacuate and back fill the system three times to insure that all of the air and moisture is out of the system.

6. The oxygen level must be below 20 ppm. In order to achieve this level, take the following steps:
(20 ppm is a reduction factor 10000 with respect to the atmospheric air). If we pump the vacuum from 1000 mbar to 100 mbar and we brake the vacuum with nitrogen, repeating the procedure 4 times, we will reach the required reduction factor (we will add 2 or 3 more cycles as a safety margin).

7. Set the final pressure to 150 mbar to ensure that the pressure differential across the gate valve is less than 50 mbar (protects the O-ring from damage when the seal plate is opened).

11.5 CALIS III commissioning: Pressure stability test with the gate valve open procedure

1. Turn off HV of all PMTs in the LSV.
2. Perform the vacuum evacuation procedure steps described in 11.3.
3. Perform the nitrogen flushing and pressurization procedure steps described in 11.4.
4. Verify that the pressure of 150 mbar is reached.

5. Loosen the ring clamp connecting the upper and lower assembly so that it can rotate.
6. Rotate the device in both directions and monitor any pressure changes due to rotation and loosening of the ring clamp.
7. Open the gate valve and observe any pressure changes in the system or LSV. If there are no variations and the system is sealed and stable, conclude that the system is gas tight. The pressure could change because we don't know exactly the pressure in the pipe.
After the opening of the valve the pressure should be stable.
8. Rotate the device in both directions and monitor any pressure changes due to rotation and loosening of the ring clamp.
9. If no pressure changes are observed, rotate the device back to the original position(defined by arm articulating toward the detector center).
10. Tighten the ring clamp.
11. Close the gate valve.
12. If done with all testing, turn on the PMT HV in LSV and resume normal data taking.

11.6 CALIS III commissioning: Vertical deployment with a source holder (without source inside) procedure

The first full deployment of CALIS III will be done without an actual source. The first test will be monitored with the PMTs off while using the veto CCD cameras to verify the location of the PIG relative to the detector.

1. Verify that the CCD cameras are operational and accessible.
2. Turn off PMT HV in the LSV.
3. Perform the vacuum evacuation procedure steps described in 11.3.
4. Perform the nitrogen flushing and pressurization procedure steps described in 11.4.
5. Verify that the pressure of 150 mbar is reached.
6. Open the gate valve.
7. Lower the PIG to the liquid level below the gate valve and observe pressure variations.
8. Lower the PIG in steps of 10 cm and carefully monitor the system through the viewport (it is fine as LSV PMTs are OFF).
9. Deploy the PIG to the fully extended position according to the previously determined stepper motor count.
10. Observe the motion with the CCD cameras.
11. Return the PIG to the home position above the gate valve by observing the arm in the viewport.
12. Close the gate valve.
13. If done with all testing, turn on the PMT HV in LSV and resume normal data taking.

If the test of lowering the PIG to the fully extended position is successful, the next test will include the articulation of the arm.

11.7 CALIS III commissioning: Deployment test with arm articulation procedure

The short 40.5 cm long arm will be mounted for this test. The PIG will be deployed to the level of the TPC and the arm will be articulated toward the cryostat.

1. Verify that the CCD cameras are operational and accessible.

2. Open the viewport.
3. Attach the tether lines.
4. Mount the 40.5 cm long arm.
5. Remove the tether lines.
6. Close the viewport.
7. Turn off PMT HV in the LSV.
8. Perform the vacuum evacuation procedure steps described in 11.3.
9. Perform the nitrogen flushing and pressurization procedure steps described in 11.4.
10. Verify that the pressure of 150 mbar is reached.
11. Open the gate valve.
12. Deploy the PIG to the center of the TPC level position according to the previously determined stepper motor count.
13. Articulate the arm.
14. Observe the motion with the CCD cameras.
15. De-articulate the arm.
16. Return the PIG to the home position above the gate valve.
17. Verify that the arm is visible in the viewport.
18. Close the gate valve.
19. If done with testing, turn on PMT HV and resume data taking.

11.8 CALIS III commissioning: Determination of the TPC position with the electric contact test procedures

The electric contact test will be conducted to verify the position of the detector with respect to CALIS III. The electric test is possible since the CALIS III is electrically insulated from CRH and detector by a 1.25 cm thick Teflon angle between the lower assembly and the gate valve. The proof of principle test has already been successfully performed during testing at Fermilab. Fig. 19 outlines the concept of the electric contact test. The goal of the test is to determine physical location of the cryostat with respect to the source using electric contact. The cryostat is grounded together with the top and CRH. There are two tests that we will conduct. The first test includes a voltmeter connected between N1 angle and CALIS III upper assembly. The voltmeter should give a closed circuit signal whenever the arm touches the cryostat. The second test will include sending a high frequency signal through cables down to the arm. The oscilloscope connected to the N1 angle at the top should pick up this signal every time the arm comes in contact with the cryostat. In this way, the x-y location of the cryostat with respect to CALIS III will be determined. Below is the step-by-step procedure of the electric contact test.

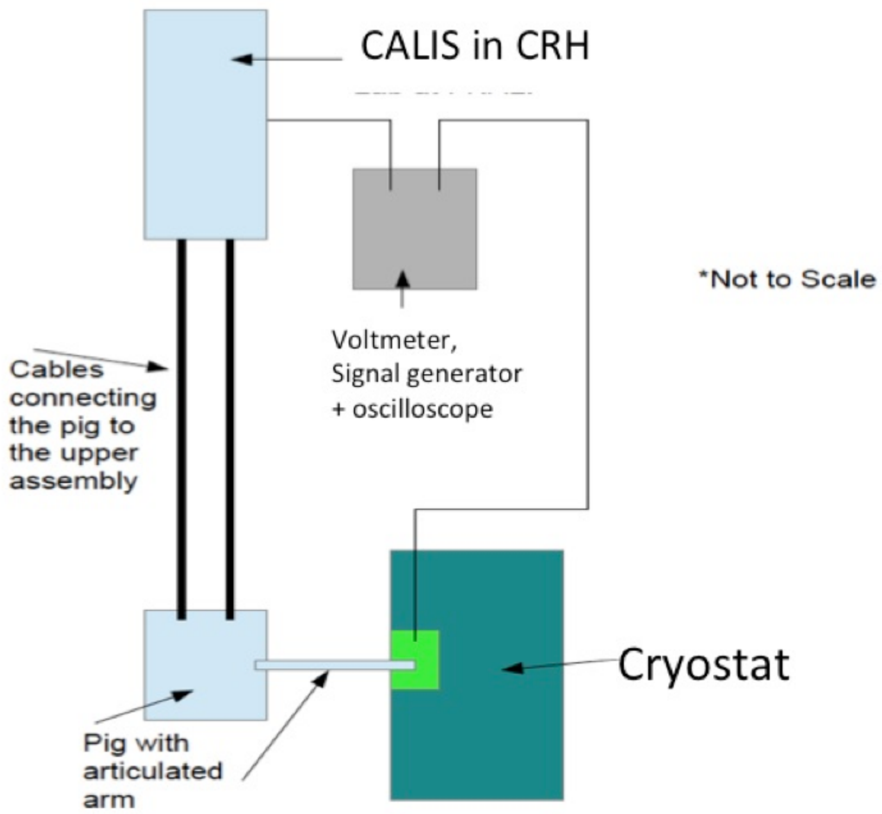

Figure 19: The sketch of the electric test. The lower assembly is electrically insulated from the CRH and cryostat with a Teflon ring placed between the lower assembly and the gate valve. There are two tests that we will conduct. The first test includes a voltmeter that should give a closed circuit signal whenever the arm touches the cryostat. The second test will include sending a high frequency signal through cables down to the arm. The oscilloscope connected to the CRH ground line at the top should pick up this signal every time the arm comes in contact with the cryostat. In this way, the physical location of the cryostat with respect to CALIS III will be determined.

1. Verify that the CCD cameras are operational and accessible.
2. Prepare voltmeter, signal generator and oscilloscope.
3. Open the viewport.
4. If 62 cm long arm is in place, proceed to turning off the PMT HV.
5. If 62 cm long arm is not attached, attach the tether lines to it.
6. Mount the 62 cm long arm with a source holder, but no source inside, according to the long arm installation procedure described in the calibration section 12.
7. Remove the tether lines.
8. Close the viewport.
9. Turn off PMT HV in the LSV.
10. Perform the vacuum evacuation procedure steps described in 11.3.
11. Perform the nitrogen flushing and pressurization procedure steps described in 11.4.
12. Verify that the pressure of 150 mbar is reached.
13. Open the gate valve.
14. Deploy the PIG to the center of the TPC level position according to the previously determined stepper motor count.
15. Rotate the entire upper assembly by 45 degrees.

16. Articulate the arm.
17. Observe the motion with the CCD cameras.
18. Connect the voltmeter between the upper assembly and the N1 flange that is connected to the cryostat.
19. Verify that it shows open circuit.
20. Loosen up slightly the ring clamp that connects upper and lower assembly by loosening the screw on the clamp for easier rotation of the upper assembly with respect to the lower assembly.
21. Slowly rotate the arm back to the cryostat and record the angular position at which electric contact is established.
22. Rotate away from the cryostat and record the angle at which the circuit becomes open again.
23. Repeat the test several times until the angle at which the contact happens is determined.
24. De-articulate the arm.
25. Proceed to the second test.
26. Rotate the arm away from the cryostat and send the high frequency pulse through the cables and arm.
27. Connect the oscilloscope to the N1 angle that is connected to the cryostat.
28. Verify that there is no pulse signal on the oscilloscope.
29. Slowly rotate the arm toward the cryostat and stop when the signal pulse shows on the oscilloscope.
30. Rotate away from the cryostat until the signal goes away.
31. Repeat the test several times until the angle at which the contact happens is determined within 1-2 degrees.
32. De-articulate the arm.
33. Rotate the upper assembly 45 degrees in the opposite direction from the central line connecting the central detector axis and the axis of the organ pipe.
34. Repeat the steps 16. to 32. in order to determine the position of the cryostat when approaching from the opposite side.
35. Rotate the pig back to the line connecting the detector axis and the CALIS IIII axis.
36. Dearticulate the arm.
37. Return the PIG to the home position above the gate valve.
38. Verify that the arm is visible in the viewport.
39. Close the gate valve.
40. If done with all testing, turn on the PMT HV in the LSV and resume normal data taking.

11.9 CALIS IIII commissioning: Light tightness test procedure

Before turning on the PMTs we must test the light tightness of the system and identify and close any potential light leaks. The following steps will be taken as a part of light leak test.

1. Perform the vacuum evacuation procedure steps described in 11.3.
2. Perform the nitrogen flushing and pressurization procedure steps described in 11.4.
3. Verify that the pressure of 150 mbar is reached.
4. Put the three light covers on the CALIS III viewports and position them carefully.
5. Secure the light cover on the main viewport with clamps.
6. Identify one PMT close to the organ pipe used for deployment, and check its dark rate on the oscilloscope at nominal high voltage.

7. Turn off all PMTs HV in the LSV.
8. Turn off lights in CRH and use red light
9. Open the gate valve.
10. Turn on the one previously identified PMT at lower HV equal to -200V of its nominal voltage.
11. Monitor its dark rate with the OD scaler software.
12. If the rate is more than two times higher than the nominal dark rate (somewhat higher dark rate is normal if PMT HV has just been turned on), cover the system with black cloth/plastic sheets, identify locations of light leaks and fix the light leaks;

utilize ash light to more easily identify the leaks.

PMTs are safe even at couple of hundred kHz rate.

13. Rotate the upper assembly clockwise and counter clockwise in 10 degree steps and monitor the dark rate to ensure no light leaks at the upper-lower assembly interface.
14. Turn on the lights and check if the dark rate has changed.
15. Turn the light off and use red light flashlight again.
16. Increase HV on the selected PMT by 50V step by step to its nominal value and verify the dark rate does not exceed two times the originally measured dark rate, at each step.
17. Rotate the upper assembly clockwise and counter clockwise in 10 degree steps at each HV setting and monitor the dark rate to ensure no light leaks at the upper-lower assembly interface.
18. Identify all light leaks, close the light leaks and put more black cover where needed, until the ark rate is less than two times the nominal PMT dark rate.
19. Turn on light in CRH and monitor the dark rate.
20. If the dark rate increases, put more black cover and search for light leaks.
21. If all light leaks are taken care of, leave the lights on; if not, plan on using red flashlight during the campaign.
22. Turn off lights in CRH.
23. Turn on all PMTs at lower HV of -200 V from nominal value.
24. Check the rate on OD scaler software. If unchanged proceed to the next steps, otherwise identify the light leaks.
25. Rotate the upper assembly clockwise and counter clockwise in 10 degree steps and monitor the rates to ensure no light leaks at the upper-lower assembly interface.
26. Turn on the lights and check rates.
27. If there is an increase, search for more leaks and seal them.
28. Turn off the lights in CRH and use red.
29. Once rates are at their original level (or less than 2 times higher) start increasing the HV on all PMTs in 50V steps.
30. Rotate the upper assembly clockwise and counter clockwise in 10 degree steps at each HV setting and monitor the rates to ensure no light leaks at the upper-lower assembly interface.
31. Verify rates with lights on and off at every HV level until nominal HV setting is used.
32. Deploy the PIG inside the LSV in stepwise fashion and monitor if PMT rates are changing due to system being deployed.
33. Rotate the upper assembly clockwise and counter clockwise in 10 degree steps to ensure no light leaks at the upper-lower assembly interface when PIG is deployed in the LSV.
34. Final configuration will be light tight enough to allow leaving the lights on during calibration, otherwise it should be at least light tight enough to allow work with a 35. Retract the PIG to the home position.

36. Close the gate valve.
37. Stop the DAQ run.

After completing the described set of tests successfully, we can proceed to the calibration campaign. The calibration campaign will incorporate the same vacuum evacuation, nitrogen flushing and pressurization steps as in the commissioning phase followed by the deployment in the detector. As part of the calibration campaign there is a specific source changing procedure described below.

12. Procedures for Calibrating the DarkSide-50 with a radioactive source

We expect to use one (maximum two) sources per day as it takes about 30 minutes to deploy the source from the home position to its position close to the outer vessel of the cryostat. After including time to attach the source to CALIS III, laser runs, and waiting time between positions, one source per day represents the best estimate at the time.

There are several different types sources and several different arm lengths that require slightly different procedures. Each individual that is going to handle a source must posses authorization to request and manage the source from the LNGS bank. Please see Federico Gabriele regarding information about the radio-protection course schedule for managing the source by LNGS EQ.

Calibration Operators should make sure to attend the radio-protection course so that they can handle the sources inside the source holders and attach the source holder to an arm for the installation in the system. The original design specification did not address different size sources and different length arms. Thus, procedures for changing arms differ for different arm lengths. Namely, the longest arm does not fit through the access port without having the source holder removed. This makes holding the arm and the source challenging while you are removing or installing the locking pins. Fortunately, the longest arm is designed for the initial characterization of the cryostat position and is not part of the standard calibration tests.

A note about a radioactive sources:

Care should be taken to minimize the exposure to any radioactive source locally, by maintaining as much distance as possible from the end of the source holder where the source is located.

General procedures to be followed during any source or arm manipulation through the viewport:

1. The gate valve must be closed during any operation that requires that the viewport be opened, insuring that nothing can fall into the veto.
2. The system must be evacuated and N2 purged according to the evacuation and nitrogen pressurization procedure, after the gate valve has been closed and before the viewport can be opened.
3. The evacuation should be performed a minimum of several hours and purged overnight before opening the viewport.
4. Removing the view port can be difficult if there is any differential pressure across the glass. This pressure should be equalized by opening valve CV3.
5. The view port should be carefully opened and all evidence of PPO should be gone by smelling, otherwise more evacuation and purging should be performed before proceeding.

12.1 Source Calibration: Insertion of the source in the source holder and arm selection procedure

1. Only an authorized person can request and manage the source from the LNGS bank.

Thus, only authorized personnel can put the sources inside the source holder, or take them out of the source holder.

2. Choose the source and bring it to CRH.

3. Place the chosen source in the source holder with a Viton ring. There are two source holders so choose the one in which the source can't.

4. The source holder must be tightly screwed until the FLANGE OF THE SOURCE HOLDER TOUCHES THE BODY OF THE SOURCE HOLDER. THIS IS A CRITICAL STEP AS IT WILL PREVENT SCINTILLATOR FROM GETTING INTO THE SOURCE HOLDER AND GETTING CONTAMINATED.

5. Confirm that the source holder is tightly screwed on so that the angle touches the body of the container.

6. Select the arm length to use for deployment.

12.2 Source Calibration: Removal of Source with Any Arm (except the longest 62cm long arm) procedure

Begin the procedure with opening the view port.

1. Follow the general procedures for source manipulation via viewport described in 12.
2. If removing the view port feels difficult, there is a differential pressure across the glass.
3. Equalize the pressure by opening valve CV3.
4. Open the viewport.
5. Install a safety line on the source arm. The safety line has a locking pin for safety:

(a) Plug the locking pin with the safety line attached into the hole just below the two locking pins that are presently holding the arm in place in the arm holder.

(b) Engage the locking pin into the arm by depressing the button of the locking pin.

(c) Release the button, once the locking pin has penetrated completely through the arm (tube), which will lock the pin securely in place.

6. Verify that the pin cannot be removed without depressing the button. At this point the arm is connected to the safety line
7. Remove the two pins that hold the arm in place with one hand, while holding the arm with the other hand.
8. Lower the arm out of the mating socket of the arm holder.
9. Manipulate the arm upward and remove it through the viewport.
10. Minimize the exposure to the source locally by maintaining as much distance as possible from the end of the source holder where the source is located (minimum distance of 30 cm should be maintained).
11. Close the view port.

12.3 Source Calibration: Installation of Source with Any Arm(EXCEPT the longest 62 cm long arm) procedure

1. Attach the safety line to the arm.

(a) Follow the general procedures for source manipulation via viewport described in 12.

(b) Plug the LONG locking pin with the safety line attached into the hole just below the holes for the two locking pins for attaching the arm to the arm holder.

(c) Engage the locking pin into the arm by depressing the button of the locking pin.

(d) Release the button, once the locking pin has penetrated completely through the arm (tube), which will lock the pin securely in place.

2. Verify that the pin cannot be removed without depressing the button. At this point the arm is connected to the safety line.
3. Verify that the arm has safety line attached.
4. Engage the source holder to the bottom of the arm and slide the latch.
5. Attach the two SHORT locking pins and verify that they are secure.
6. All of the pins used should always face in the outward direction towards the viewport.
7. Open the viewport; if removing the view port feels difficult, there is a differential pressure across the glass.
8. Equalize the pressure by opening valve CV3.
9. Open the viewport.
10. Lower the arm with the source attached into the viewport , navigating the hardware below the viewport.
11. When the top of the arm is low enough, engage the arm into the arm holder.
12. Secure the arm by inserting the two locking pins.
13. Verify that the locking pins are secure by pulling on each of the pins.
14. Remove the safe line with locking pin.
15. Close the viewport.
16. Proceed the CALIS IIII cleaning procedure after opening the viewport.

Begin the procedure with opening the view port.

1. Follow the general procedures for source manipulation via viewport described in 12.
2. If removing the view port feels difficult, there is a differential pressure across the glass.
3. Equalize the pressure by opening valve CV3.
4. Open the viewport.
5. Install a safety line on the source arm. The safety line has a locking pin for safety:

(a) Plug the locking pin with the safety line attached into the hole just below the two locking pins that are presently holding the arm in place in the arm holder.

(b) Engage the locking pin into the arm by depressing the button of the locking pin.

(c) Release the button, once the locking pin has penetrated completely through thearm (tube), which will lock the pin securely in place.

6. Verify that the pin cannot be removed without depressing the button. At this point the arm is connected to the safety line.
7. Remove the two pins that hold the arm in place with one hand, while holding the arm with the other hand.
8. Lower the arm out of the mating socket of the arm holder.
9. Manipulate the arm upward, navigating through some of the hidden hardware located above the viewport.
10. Raise the arm high enough to see the source holder.
11. Connect a safety line with a locking pin to the source holder.
12. Verify that the locking pin cannot be removed without depressing the button.

13. Remove the two locking pins from the source holder while holding the arm and source holder in one hand.

14. Minimize the exposer to the source locally by maintaining as much distance as possible from the end of the source holder where the source is located.

15. Remove the source holder from the viewport and place it carefully on a side.

16. Lower the arm below the viewport.

17. Tilt the arm outward to obtain clearance and remove the arm through the viewport.

18. Close the viewport.

12.5 Source Calibration: Installation of Source with Long Arm(62 cm) procedure

1. Follow the general procedures for source manipulation via viewport described in 12.

2. Attach the safety line to the arm.

   (a) Plug the LONG locking pin with the safety line attached into the hole just below the holes for the two locking pins for attaching the arm to the arm holder.

   (b) Engage the locking pin into the arm by depressing the button of the locking pin.

   (c) Release the button, once the locking pin has penetrated completely through the arm (tube), which will lock the pin securely in place.

3. Verify that the pin cannot be removed without depressing the button. At this point the arm is connected to the safety line.

4. Attach the safety line to the source holder:

   (a) Plug the SHORT locking pin with the safety line attached into the hole on the source holder.

   (b) Engage the SHORT locking pin into the source holder by depressing the button the locking pin.

   (c) Release the button, once the locking pin has penetrated completely through the source holder, which will lock the pin securely in place.

5. Verify that the pin cannot be removed without depressing the button. At this point the source holder is connected to the safety line.

6. Verify that the arm and the source holder must have safety lines attached to each of them before putting them through the viewport.

7. Put the long arm through the viewport angling it downward, making sure to clear the hardware located below the viewport.

8. When arm has been successfully navigated between the hardware that is located lower than the viewport, the arm can enter the viewport completely.

9. Once the arm is completely within the viewport, raise it high enough to attach the source to the bottom of the arm.

10. Place the source holder with the safety line attached through the viewport.

11. Engage the source holder to the bottom of the arm and slide the latch.

12. Attach the two locking pins and verify that they are secure.

13. All of the pins used should always face in the outward direction towards the viewport.

14. Remove the safety line from the source holder.

15. Lower the arm with the source attached, navigating the hardware below the viewport.

16. When the top of the arm is low enough, engage the arm into the arm holder.

17. Secure the arm by inserting the two locking pins.

18. Verify that the locking pins are secure by pulling on each of the pins.

19. Remove the safe line with locking pin.

20. Close the viewport.

21. Proceed the CALIS III cleaning procedure after opening the viewport.

12.6 Source Calibration: Cleaning of the CALIS III after Source Manipulation through the Viewport procedure

Once a source or arm change has been completed the air must be removed and replaced with clean N2.

1. Replace and close the viewport.
2. Close CV3.
3. Verify that CV1 is closed.
4. Open CV2 to the vacuum pump.
5. Evacuate out all the air that has entered the system for 30 minutes. After 30 minutes
close CV2.
6. Repeat 11.3 and 11.4 several times (6-7).
7. Open CV1.
8. Backfill with N2 to 150 mbar.
9. Close CV1.
10. Open CV2.
11. Evacuate again.
12. After the second evacuation close CV2.
13. Open CV1.
14. Increase the pressure to 150 mbar.
15. The gate valve can now be opened to deploy the source.

12.7 Source Calibration: General deployment steps procedure

The choice of the sources, duration of runs and selection of positions are described in the calibration plan and justified by the simulation studies. Here is a brief, generic outline of the deployment procedure for any source.

1. Perform vacuum evacuation procedure 11.3.
2. Perform nitrogen flushing and pressurization procedure 11.4.
3. Verify that all view ports have covers and the main viewport cover is secured with a clamp.
4. Open gate valve.
5. Monitor pressure changes and proceed if pressure appears stable.
6. Choose step position corresponding to position within neutron veto using corresponding chart of positions.
7. Start deployment in GUI by entering predetermined step count or z position.
8. Once PIG has reached specified position, wait 10 minutes for stabilization.
9. Read the required dial number on the hand wheel to articulate the arm to horizontal position.
10. Slowly rotate the hand wheel until dial indicates that the arm is in horizontal position.
11. Once at the desired position, wait 10 minutes for stabilization.
12. Begin laser run.
13. Option to rotate, in phi, the system.
    (a) Choose desired rotation angle.
    (b) Loosen the clamp between upper and lower assemblies.
    (c) Slowly rotate upper assembly to desired position as indicated by the band attached.
    (d) Once at position, close clamp and wait 10 minutes for stabilization.
14. Begin data taking.

15. At the end of data taking, prepare to de-articulate arm, reverse rotation in phi if it is needed and retract PIG.

16. De-articulate arm to vertical position, marked as zero on dial.

17. Wait 10 minutes for stabilization.

18. If the option was taken to rotate in phi, follow the steps below.

(a) Release clamp between upper and lower assemblies.

(b) Rotate upper assembly in reverse direction from before, towards the zero mark.

(c) Once at zero mark, close clamp, and wait 10 minutes for stabilization.

19. Retract PIG to home position, enter step position 0 on computer interface. Press Start Move button.

20. Once PIG has reached home position, close gate valve.

21. Evacuate and purge CALIS III to remove scintillator using vacuum evacuation and nitrogen flushing and pressurization procedures.

22. Leave the system over night to ensure that the system is properly purged of leftover LS.

13. Emergency Procedures

The main emergency that may take place is in case when the motor drive has failed and can no longer extract the pig. There two are types of two failure scenarios. In any case, the first step of the emergency procedure is to TURN OFF PMT HV IN LSV and stop the DAQ.

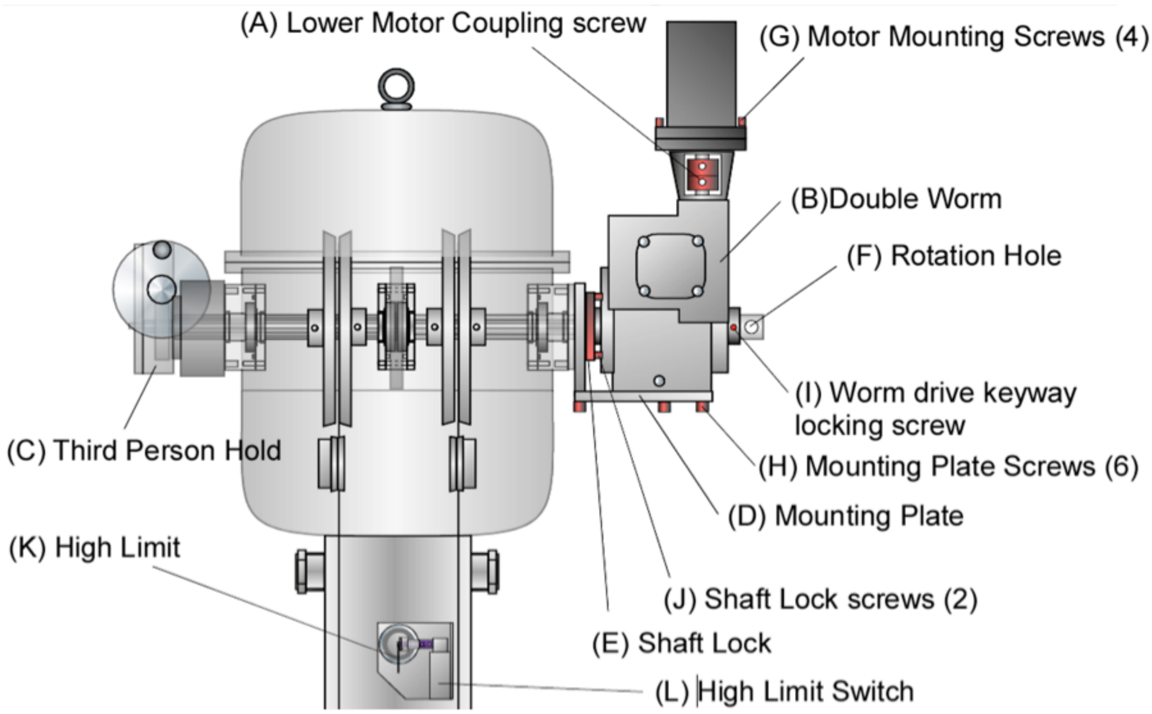

Figure 20: Details of the connections of the motor drive and connections to the shaft and spools located in the upper assembly.

- The first type of failure is that the motor is unresponsive and or the motor controls can no longer drive the double worm gear drive. In this case the following steps should be taken:

  1. The motor should be removed by removing the four mounting screws that hold it to the double worm drive (Fig. 20-G).

  2. Slowly rotate the motor until the motor coupling lower screw can be access and loosened (Fig. 20-A).

3. Once the lower motor coupling screw is loosened, lift up the motor and remove it.

4. The worm drive will hold the load (PIG) without the motor connected.

5. Remove the motor coupling from the motor and place it back on the double worm drive to help operate the drive manually (Fig. 20-A).

6. Manual operation of the drive will take a very long time because of the slow speed at which the double worm gear is being rotated.

7. In addition to the motor coupling, an electrical drill can be connected to manually drive the worm drive at a greater rate.

- The second type of failure is that the double worm gear has locked up and the servomotor cannot move the worm drive and the worm drive cannot be moved manually. In this case, the following steps should be taken that require at least to, and preferably three people to participate.

1. The worm drive needs to be removed. It is important to transfer the load (weight of the PIG) to the shaft lock (Fig. 20-E), before the worm drive is completely removed.

   (a) This operation will take at least two people: one to hold the worm drive from rotating while the other removes the lower mounting plate. (Fig. 20-D).

   (b) A third person can help hold the load by keeping the articulating drive from rotating on the main shaft (Fig. 20-C).

   (c) Once people are in place holding the motor drive from rotating, remove the six mounting screws of the motor mounting plate (Fig. 20-H).

   (d) The two screws (Fig. 20-J) must be loosened on the shaft lock.

   (e) Then, slide the shaft lock (Fig. 20-E) into the lock position.

At this point the worm drive mounting plate should be completely removed.

2. Then the person(s) holding the drive to keep it from rotating, rotate the motor drive a few degrees until the shaft lock is pushed into place. This will lock the motor drive shaft. At this point the shaft lock is slid inwards and the hexagon shape of the shaft is engaged into the shaft lock.

3. Then, the two shaft lock screws can be tightened securing the shaft from rotating.

4. Loosen the worm gear keyway locking screw (Fig. 20-I) to allow the worm drive to be removed.

   (a) The worm drive is removed by sliding it off the shaft while the shaft lock is holding the load.

   (b) Place a 12 to 24" threaded rod with nuts or a metal rod in the shaft rotation hole.

   (c) Loosen the shaft lock and slide it back, while one person holds the rod in the shaft.

   (d) Transfer the load to be transferred to the person(s) holding the bar, that is placed in the rotation hole.

5. Rotate the bar clockwise to raise the PIG into the home position watching it in the viewport.

6. Slide the shaft lock back to lock the shaft.

7. Tighten the shaft lock screws.

8. Close the gate valve, while the shaft lock holds the PIG securely.

9. This completes the manual extraction.

14. Operations and Shifts Requirements

There will be at least two person/shift.

Leading personnel involved in the operation and DarkSide operation personnel contact numbers and email address:

Name	Cellphone	E-mail
Giuseppe Bonfini	+39-328-114-7392	giuseppe.bonfini@lngs.infn.it
Augusto Brigatti	+39-340-376-7537	augusto.brigatti@mi.infn.it
Paolo Cavalcante	+39-349-099-2651	paolo.cavalcante@gmail.com
Nicola Canci	+39-328-678-7744	nicola.canci@lngs.infn.it
Francesco di Eusanio	+39-348-884-2104	francesco.dieusanio@lngs.infn.it
Erin Edkins		eee@hawaii.edu
Federico Gabriele	+39-328-169-3206	federico.gabriele@lngs.infn.it
Cristiano Galbiati	+39-338-667-9111	galbiati@Princeton.EDU
Augusto Goretti	+39-338-648-2463	agoretti@Princeton.EDU
Biranne Hackett		bhackett@hawaii.edu
Cary Kendziora		clk@fnal.gov
Andrea Ianni	+39-338-936-7279	ianni@princeton.edu
George Korga	+39-328-622-0039	george.korga@lngs.infn.it
Paolo Lombardi	+39-347-377-1723	paolo.lombardi@mi.infn.it
Jelena Maricic		jelena@phys.hawaii.edu
Michele Montuschi	+39-392-849-6592	michele.montuschi@lngs.infn.it
Bernd Reheinold		bernd@hawaii.edu
Sergio Parmeggiano	+39-339-133-9559	sergio.parmeggiano@mi.infn.it
Ettore Segreto	+39-338-336-8992	ettore.segreto@lngs.infn.it
Yury Suvorov	+39-340-862-9743	yura.suvorov@lngs.infn.it