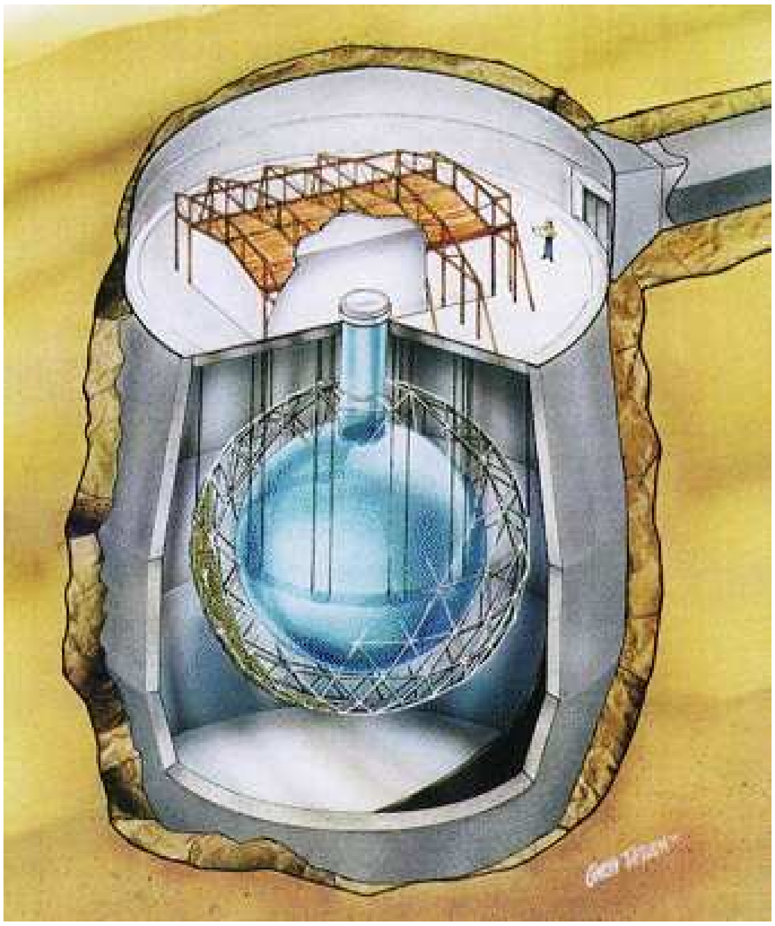
SNO Calibration

- **Optical**
  - Phototube timing, threshold, occupancy.
  - Optical properties of: D_2O, H_2O, Acrylic as a function of wavelength.
  - Sources:
    - Laserball
- **Energy and Event Characteristics**
  - Absolute energy scale (Nhits/MeV).
  - Energy response as a function of event position and direction.
  - Angular resolution.
  - Sources:
    - ^{16}N — 6.131 MeV γ
    - p-t source — 20 MeV γ
    - ^{24}Na — 2.8 and 1.4 MeV γ
    - ^{8}Li — 14 MeV end point β
- **Neutral Current**
  - Neutron capture efficiency (function of event position in D_2O)
  - Sources:
    - ^{252}Cf
    - ^{17}N
- **Backgrounds**
  - U and Th decay products
  - Sources:
    - Proportional Counter U and Th Source

Source in Red have been deployed

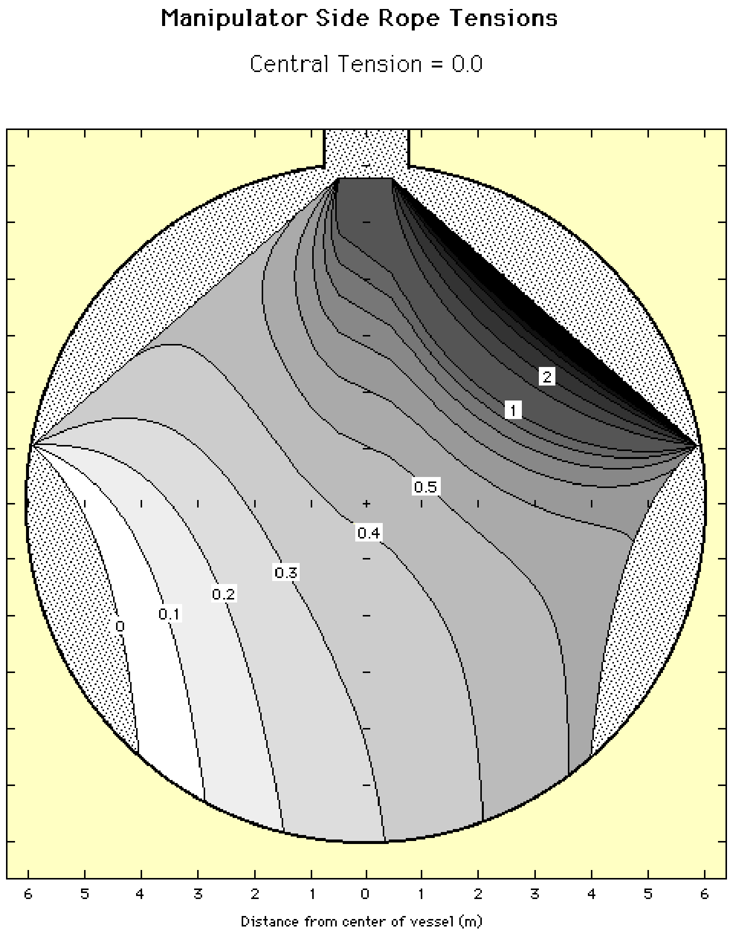
The Sudbury Neutrino Observatory Calibration System



Fraser Duncan, *Queen's University*
For the SNO Collaboration

Calibration Manipulator

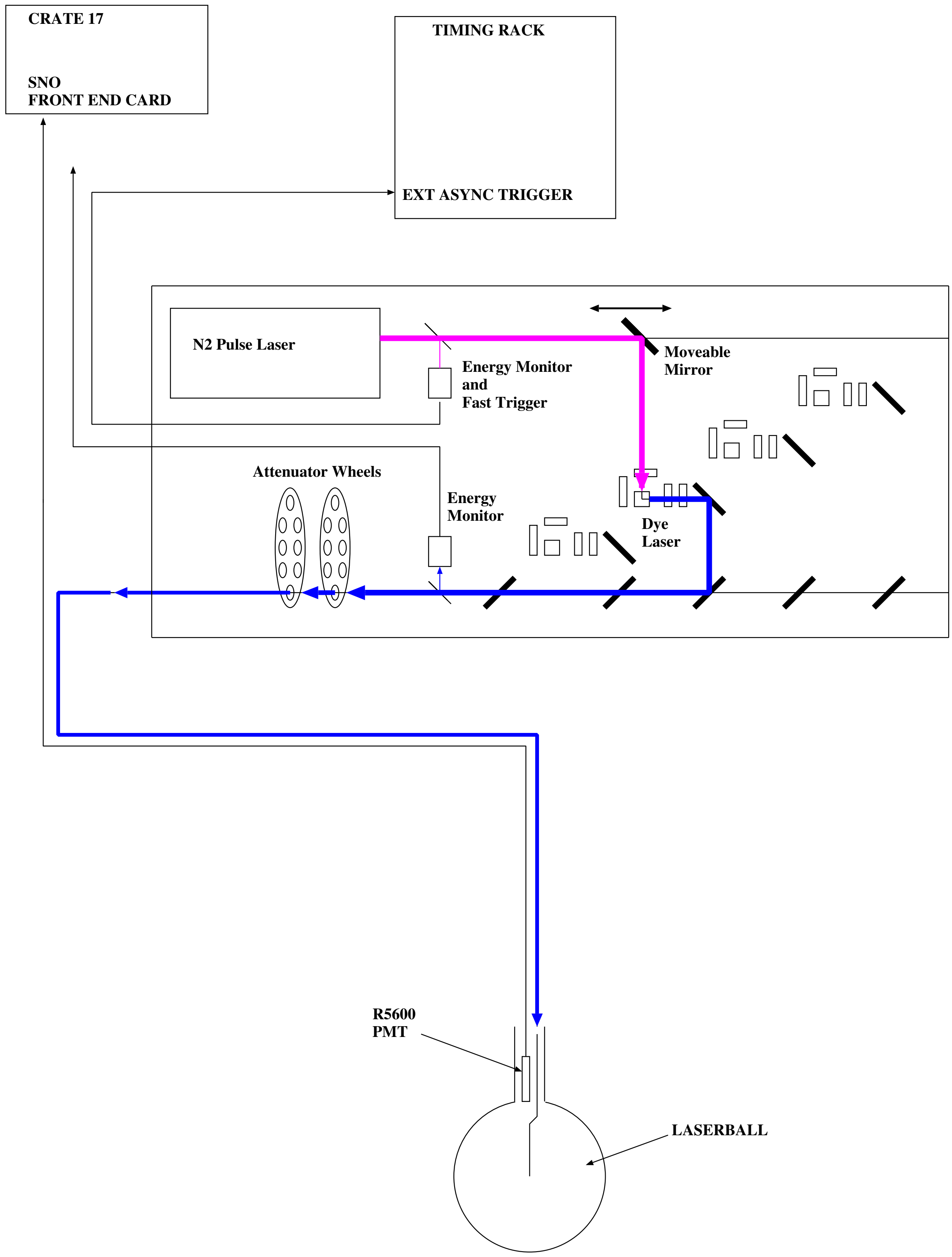
Calibration sources are deployed into the SNO detector using a computer controlled manipulator system. The manipulator can lower a source into the *acrylic vessel* (AV) containing the heavy water or into the light water volume between the acrylic vessel and the *photomultiplier support structure* (PSUP). Sources deployed into the acrylic vessel are positioned with a system of three ropes that move the source in one of two planes (North/South or East/West). Sources are lowered into the light water volume in a single axis mode down one of six calibration "guide tubes". Each source requires different services (electrical, gas, fibre optics, trigger signals) which are carried through an "umbilical". One of the design criteria of the manipulator system is to allow deployment of sources without breaking either the radon seal or the light seal on the detector. The latter feature allows the detector to continue data taking while sources are being inserted or retracted.

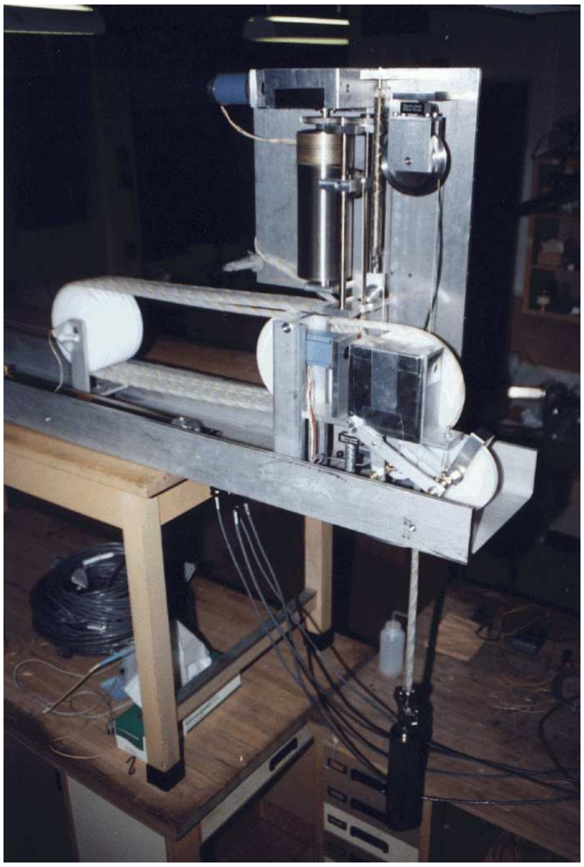


This figure shows the tension of the right side rope relative to the source weight in different regions of the detector. The side ropes for a 100 N source can be operated over the range of 0.05 to 2.0 which covers 65% of the manipulator plane.

Optical Calibration

The primary optical calibration device is a 337 nm nitrogen pulse laser with a 0.7 ns pulse width. This laser can be used directly or to excite one of four dye lasers. The laser light is transported through a fibre optic bundle into a "laserball" that diffuses the light into the detector isotropically.



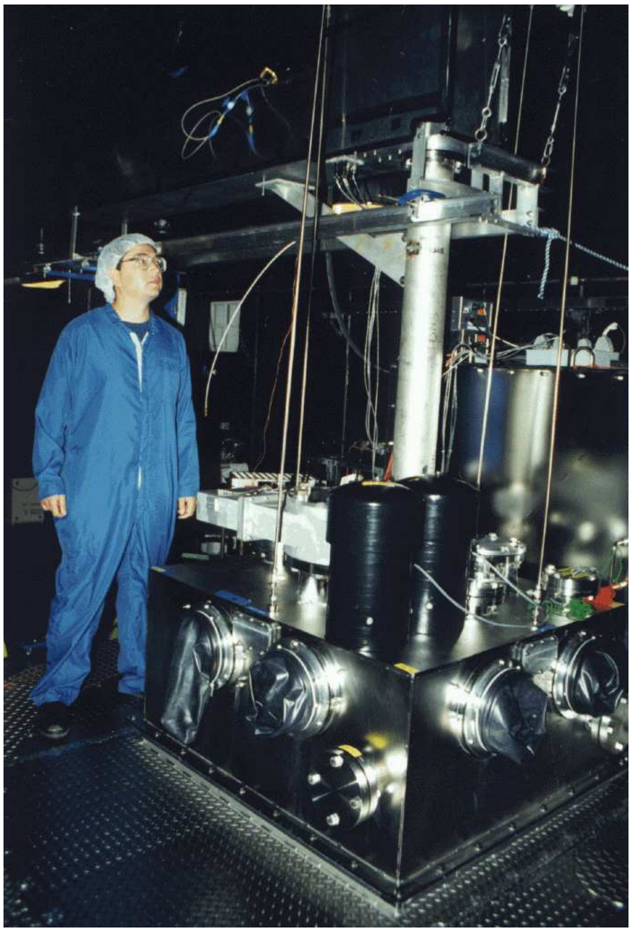


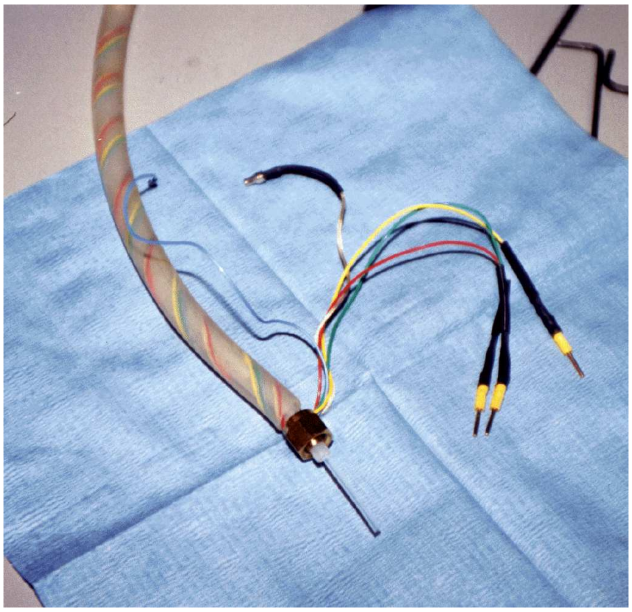
URM

Each source is supported by an Umbilical Retrieval Mechanism (URM) which supplies services to the source through an umbilical. This is a prototype unit being tested at Queen's without it's radon and light cover. The umbilical is wound on the white pully sets while the rope is taken up on the vertical drum. The carriage and weight assembly can be seen below the unit.

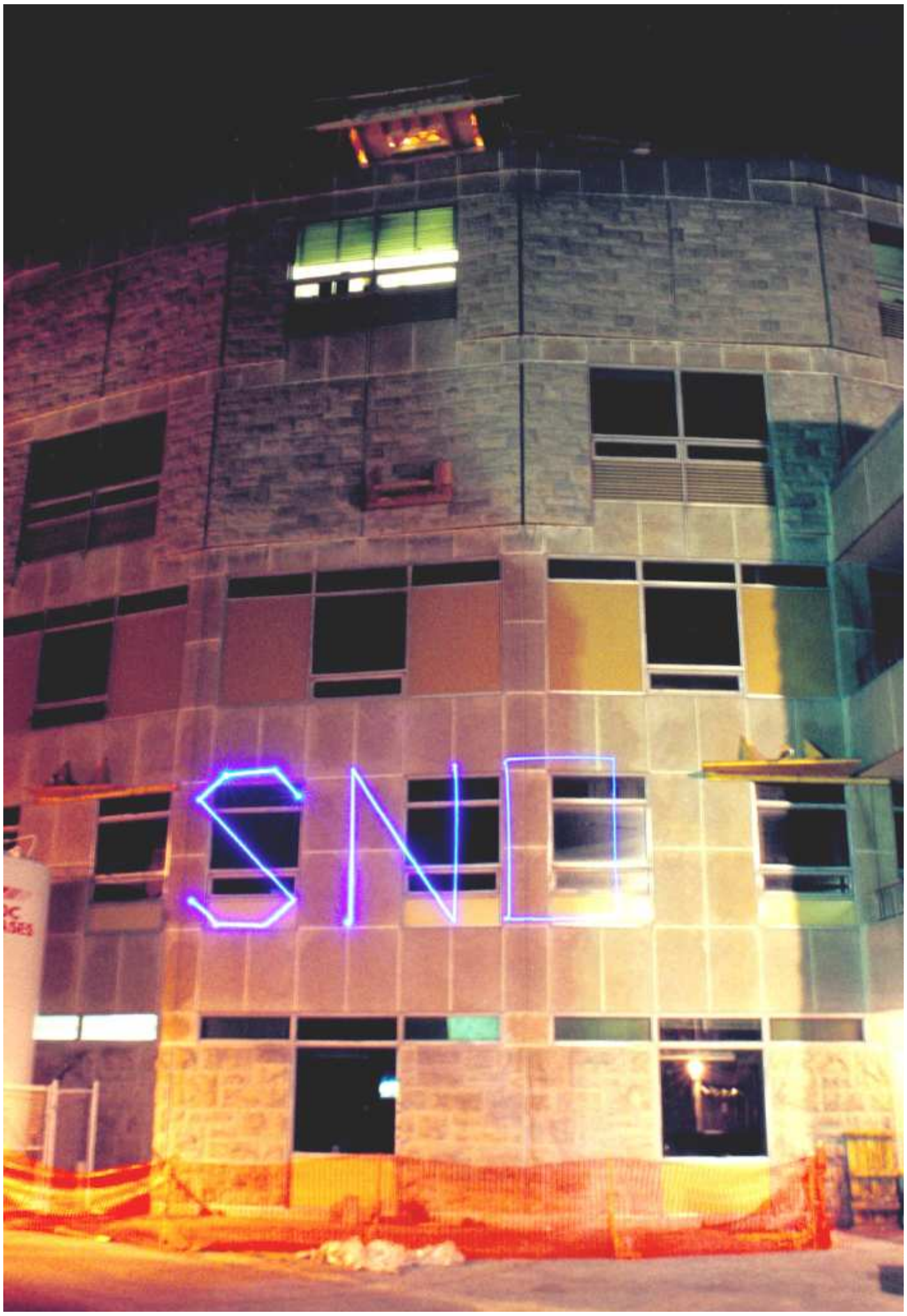
Universal Interface

Sources are deployed into the heavy water through the Universal Interface located over the top of the AV neck. The Umbilical retrieval mechanisms are mounted on a glovebox that is used to attach the side ropes to sources. When not in use, sources are retracted up into a "source tube" above the glove box and sealed off by a gate valve.





The manipulator system was tested at Queen's by constructing a full scale mockup on the side of the 5 story physics building which is almost exactly the same height as the AV. The positioning accuracy of the manipulator was demonstrated one night by the graduate students who put a blue LED on the source and ran a command file "SNO.CMD".

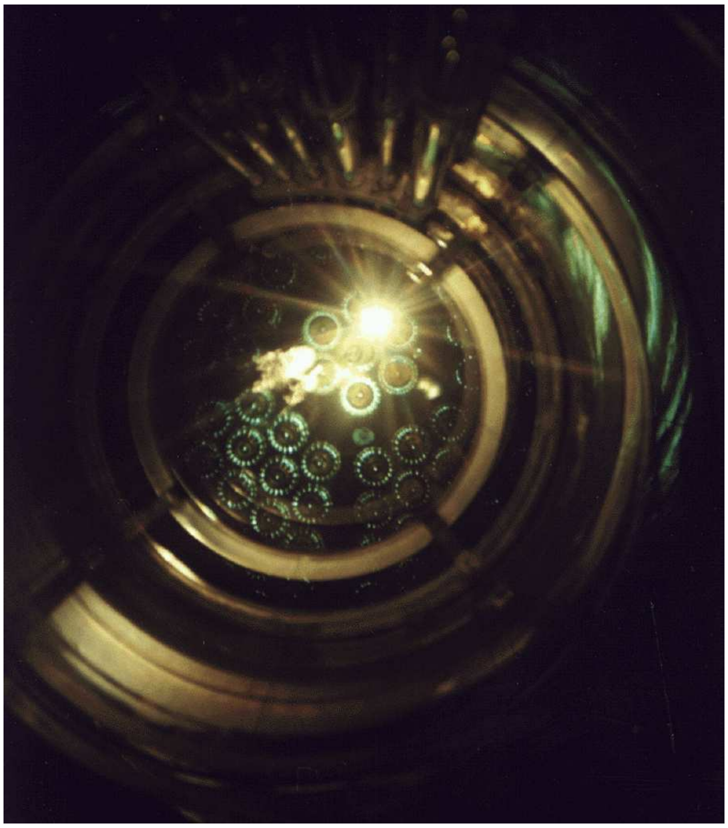


The nitrogen pulse laser is located in the copper box on the lower left which provides RF shielding from the 15 kV spark used to generate the laser pulse. The dye lasers are located on the optical table at the back of the cabinet. The intensity of the laser light is selected with the two filter wheels on the lower right. The light is then transmitted to the source in the detector through a 50 m fibre optic cable.

This photograph shows the laserball lowered out of the bottom of a source tube below a URM. The white sphere is the “laserball”, a 4” quartz flask with a diffusing material to produce approximately isotropic light in the detector.

Guide Tubes

This photograph shows a URM positioned on one of the guide tubes used to lower sources into the ligh water volume between the Acrylic Vessel and the PSUP. The entrance to another guide tube can be seen in the lower right corner of the picture.

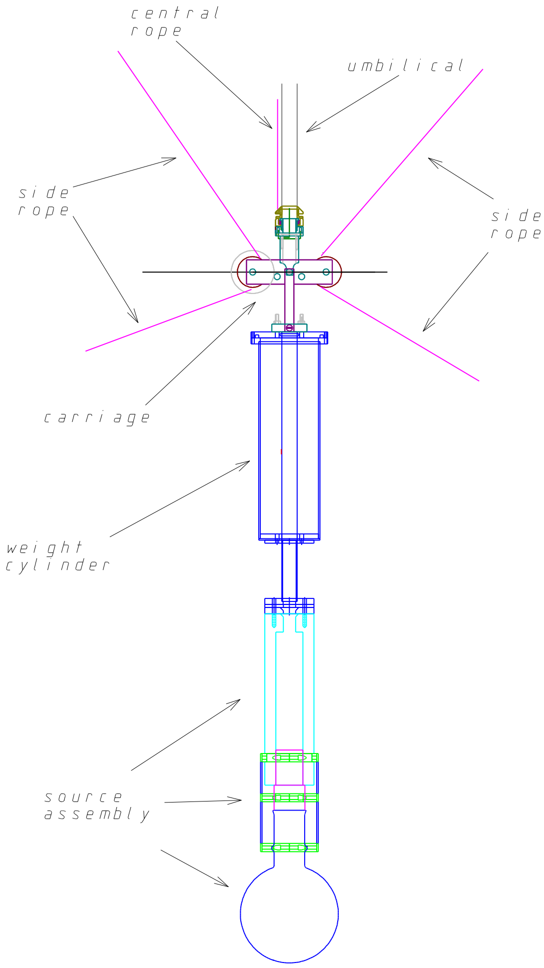


Neck Ring

Looking down the neck into the detector. The manipulator rubbing ring is located at the base of the neck with the D_2O water pipes at the top of the picture. 14.5 m below the rubbing ring are the PMTs at the bottom of the detector.

Umbilical

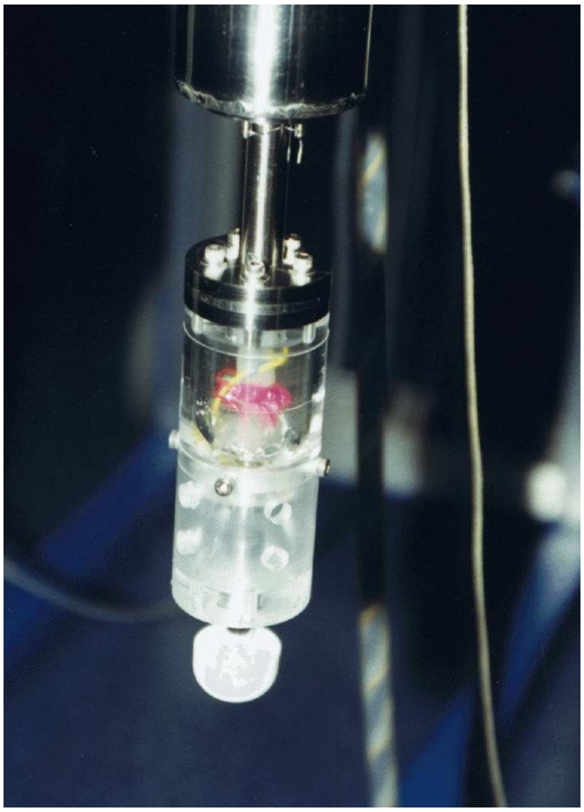
Umbilicals carry services to source. This is the N16 umbilical carrying gas to and from the source and a PMT signal.



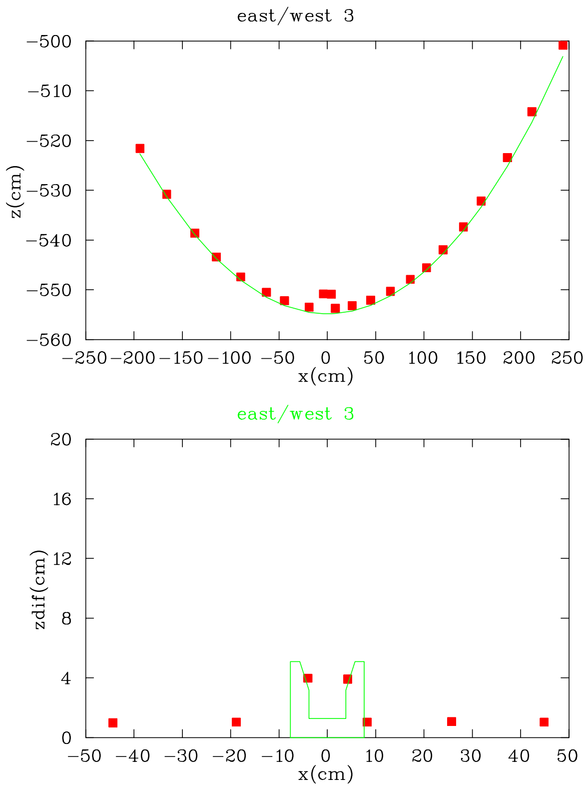
Sources

Sources are mounted on a carriage and weight assembly to which the central and side ropes are attached. Source Carriage Assembly. Sources are mounted on a carriage.

Source Positioning



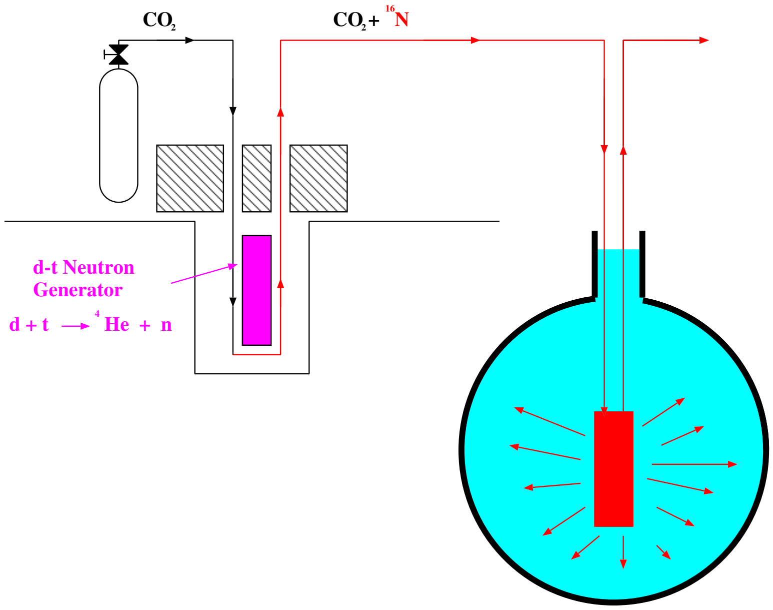
In addition to the tests at Queen's, the manipulator positioning accuracy was measured in the detector itself. A "footswitch" was placed on the manipulator. Contact with the bottom of the acrylic vessel was indicated by a switch closure. The footswitch was used to map out the shape of the vessel over a range of $\pm$ 2.5 m from the central axis.



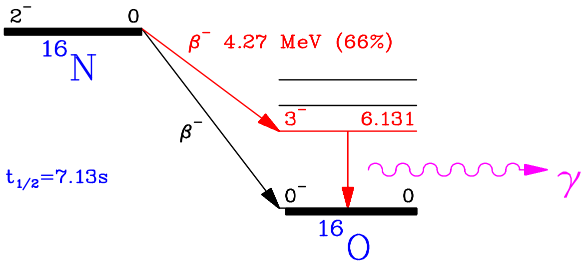
The figures on the left show a "bottom scan" of the detector. The top figure shows the curvature of the spherical vessel. The "blip" at the centre is actually a fixture used by the water systems. The bottom plot shows a close up of this fixture with points measured by the footswitch. These studies indicate that near the bottom of the vessel the positioning accuracy is 2 cm. In the upper quadrants of the detector the accuracy degrades to 10 cm.

^{16}N Source
β tagged γ

^{16}N is produced by flowing CO_2 past a d-t neutron generator. The CO_2 carries the ^{16}N which has a 7 second half life through an umbilical into the source which is deployed in the detector.



^{16}N undergoes a $\beta\gamma$ decay with the 6.2 MeV γ escaping into the water where it converts. The β stops in the scintillator producing a light pulse detected by a PMT. This PMT signal is used to tag the gamma ray.



^{252}Cf Neutron Source

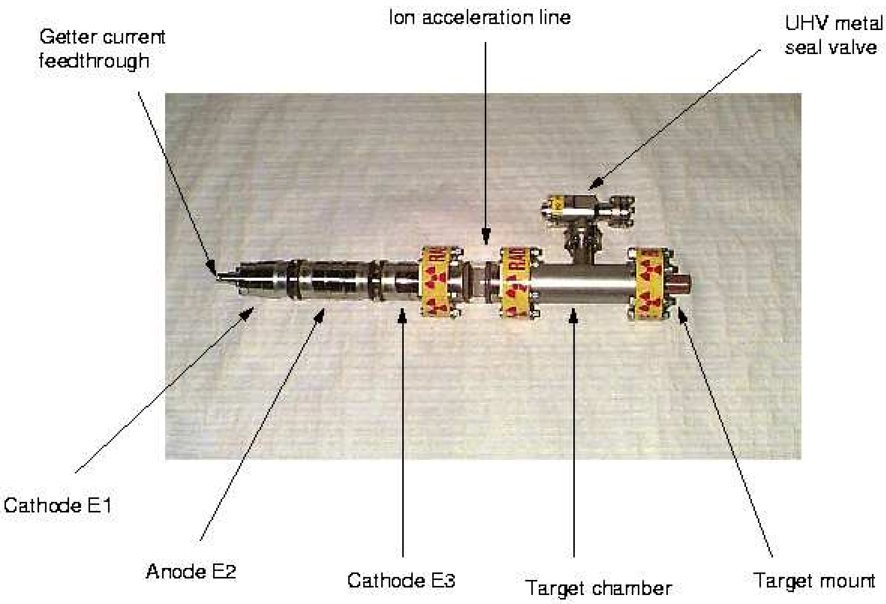
An acrylic encapsulated $0.001\mu Ci$ ^{252}Cf fission neutron source producing approximately 1 neutron per second. Neutron sources are used to measure the Neutral Current detection efficiency as a function of position.

pT Source

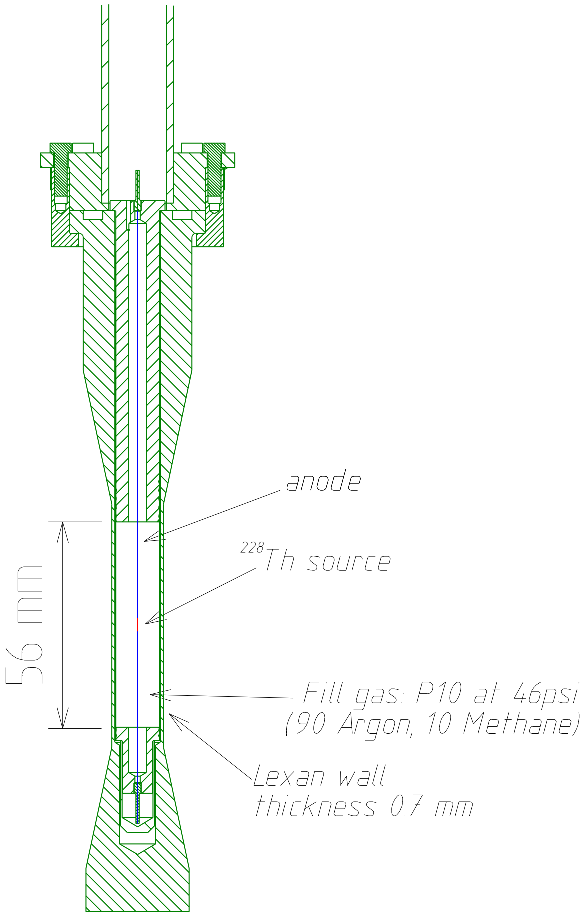
The pT source is a small 18 kV accelerator that produces 19.8 MeV gamma rays via the

$$^{3}H(p,\gamma)^{4}He$$

reaction. The accelerator will be placed in a water tight housing and lowered into the detector with the manipulator.



Proportional Counter Source



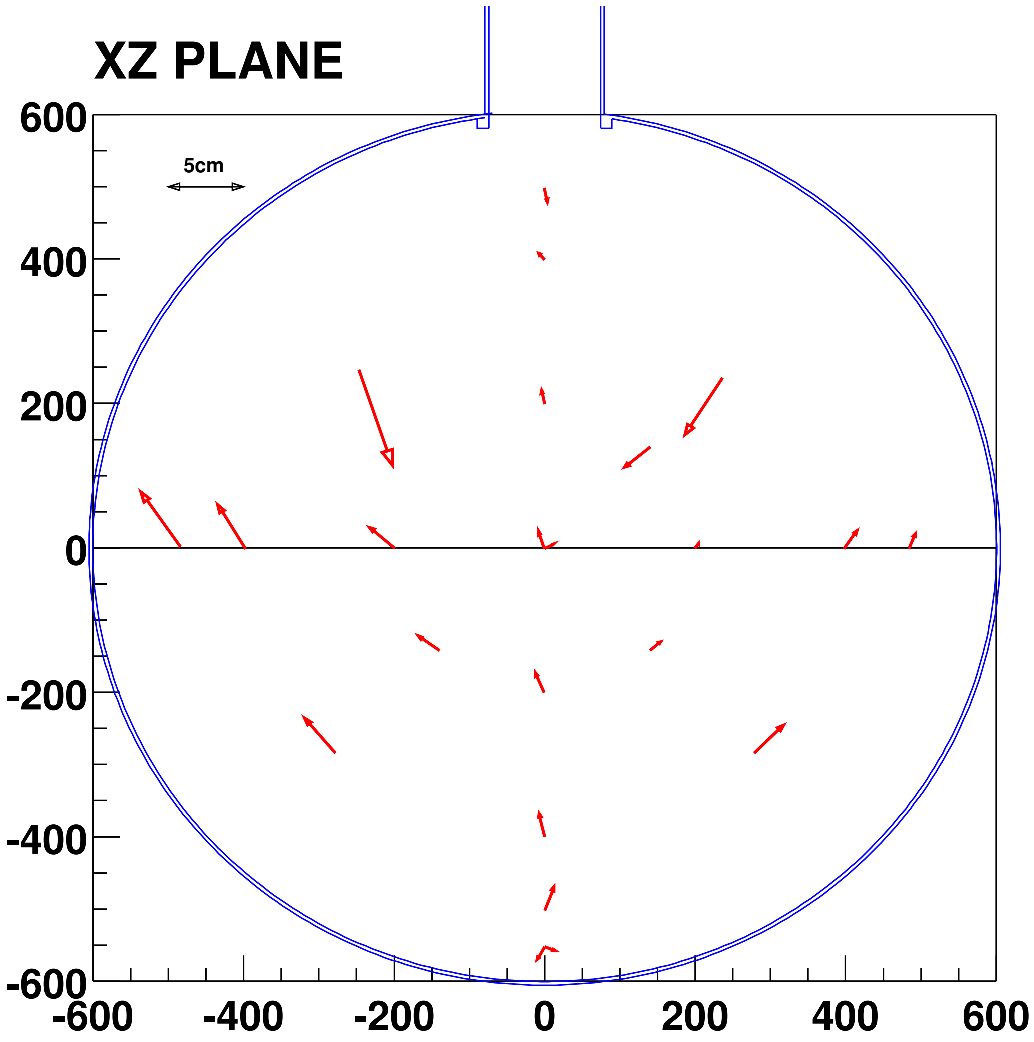
The low energy background contributions from the U and Th chain can be investigated with the Proportional Counter Source (PCS). A small amount of a radioisotope is deposited onto the anode of a small proportional counter. The walls of the counter are thin enough to allow the β to escape with minimal energy loss. The proportional counter operates with 46 psi of P10 and an anode voltage of 2300V.

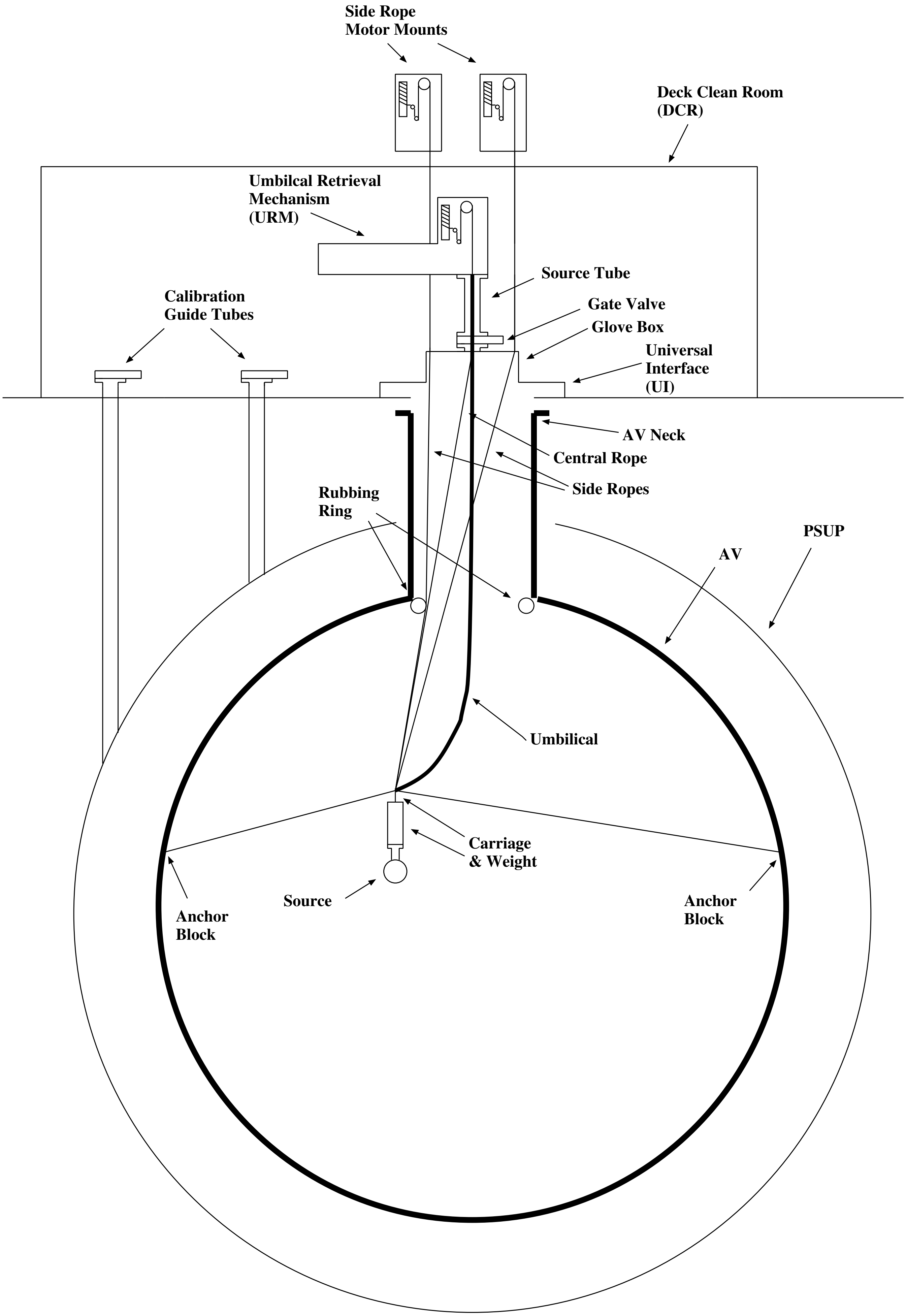
The first source to be deployed will be 50-100 bq ^{228}Th. Because the proportional counter can discriminate between α and β particles, particular decay sequences can be selected.

- β-α delayed coincidence from the $^{212}\mathrm{Bi}\rightarrow^{212}\mathrm{Po}\rightarrow^{208}\mathrm{Pb}$ transition. β (low amplitude pulse) and α (large amplitude pulses) are separated by enough time so that they can be clearly resolved.
- β-α delayed coincidence from the $^{212}\mathrm{Bi}\rightarrow^{212}\mathrm{Po}\rightarrow^{208}\mathrm{Pb}$ transition. β (small pulse) and α (large pulse) are so close together in time that the two pulses can not be resolved, and the event looks like a large pulse observed in the PCS in coincidence with SNO.
- Single β (small pulse) observed primarily due to the $^{208}\mathrm{Tl}\rightarrow^{208}\mathrm{Pb}$ β-γ decay. This event should produce a lot of light in SNO (^{208}Tl has a 5MeV Q-value) due to the combination of the β and the 2.6 MeV γ in coincidence with the PCS.

Comparison Between Manipulator Positioning and Event Reconstruction

The figure below shows a comparison the manipulator positioning and event reconstruction. The base of each arrow is a manipulator position of the laserball. The arrow points towards the mean reconstructed position with the length proportional to the size of the discrepancy. A 5 cm error bar is shown at upper left for comparison. Along the central axis and near the bottom of the detector, the discrepancy is at or below 2 cm. The larger discrepancy in the upper regions of the acrylic vessel are consistent with the expected manipulator precision. Largest difference 8 cm.





Side Rope
Motor Mounts
Deck Clean Room
(DCR)
Umbilcal Retrieval
Mechanism
(URM)
Source Tube
Calibration
Guide Tubes
Gate Valve
Glove Box
Universal
Interface
(UI)
AV Neck
Central Rope
Side Ropes
Rubbing
Ring
PSUP
AV
Umbilical
Carriage
& Weight
Source
Anchor
Block
Anchor
Block

This is the layout of the previous 16 pages on the poster.