

Liquid Helium Refill Shifts at the Cryogenic Underground Observatory for Rare Events

A Senior Project

presented to

the Faculty of the Physics Department

California Polytechnic State University, San Luis Obispo

In Partial Fulfillment

of the Requirements for the Degree

Bachelor of Science

by

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## Nomenclature

$c$	= specific heat
$e^-$	= electron
LHe	= liquid helium
mbar	= millibar
mK	= millikelvin
$m$	= mass
$n$	= neutron
$p$	= proton
TeO <sub>2</sub>	= tellurium dioxide
$\beta$	= beta decay (single)
$\Delta E$	= change in energy
$\Delta T$	= change in temperature
$\nu$	= neutrino
$\bar{\nu}_e$	= electron-type antineutrino
$0\nu\beta\beta$	= neutrinoless double beta decay
$2\nu\beta\beta$	= double beta decay

## Acronyms

CRESST	Cryogenic Rare Event Search with Superconducting Thermometers
CUORE	Cryogenic Underground Observatory of Rare Events
LHe	Liquid helium
LN2	Liquid nitrogen
LNGS	Laboratori Nazionali del Gran Sasso
TTT	Three Towers Test

## Table of Contents

<b>CUORE Experiment Overview</b>	<b>4</b>
<i>Three Towers Test</i>	<b>5</b>
<i>Cooling System</i>	<b>6</b>
<b>Refill Shifts</b>	<b>7</b>
<i>Safety</i>	<b>7</b>
<i>Liquid Helium Recovery System</i>	<b>8</b>
<i>Main Bath Refill</i>	<b>12</b>
<i>Liquid Nitrogen Refill</i>	<b>16</b>
<i>Shift Conclusion</i>	<b>18</b>
<b>Acknowledgements</b>	<b>20</b>
<b>References</b>	<b>20</b>
<b>Appendix A</b>	<b>21</b>
<b>Appendix B</b>	<b>23</b>

## CUORE Experiment Overview

The mission of the Cryogenic Underground Observatory for Rare Events (CUORE), located at the Gran Sasso National Laboratory (Laboratori Nazionali del Gran Sasso, or LNGS) in Assergi, Italy, is to study the behavior of neutrinos in order to improve the Standard Model of Physics. Currently, this model states that there exist three different types of neutrinos – electron, muon, and tau – each with their own partnering antiparticle, for a total of six distinct neutrino particles. This concept is known as the Dirac Model for neutrinos, and up to the present, measurements of neutrino behavior have shown this to be the case. However, a substantial population of scientists believes that another model, known as the Majorana Model, might be more accurate in describing the nature of neutrinos. Ettore Majorana postulated that only three distinct neutrinos exist and that each type of neutrino functions as its *own* antiparticle. CUORE’s objective is to observe a reaction in which two identical neutrino particles will annihilate each other, effectively proving the Majorana Model to be correct.

When a neutron inside an atom’s nucleus spontaneously decays, the product particles are a proton, an electron, and an electron-type antineutrino:



Due to interactions via the strong force inside the nucleus, the proton remains stationary in the nucleus while the electron, commonly called a beta particle, and antineutrino escape the nucleus. This process is called *beta decay* ( $\beta$ ), illustrated in Figure 1(a). When two beta decays occur simultaneously in the same nucleus, and two electrons and two antineutrinos exit the nucleus, it is called *double beta decay*. In ordinary double beta decay ( $2\nu\beta\beta$ ), which can be seen in Figure 1(b), two electrons and two antineutrinos escape the nucleus and zoom off into space. A special case of double beta decay which has yet to be observed is called *neutrinoless* double beta decay ( $0\nu\beta\beta$ ), seen in Figure 1(c). The name of this process suggests exactly what is believed to occur – the particles produced in the process are two protons and two electrons, meaning the reaction is neutrinoless.

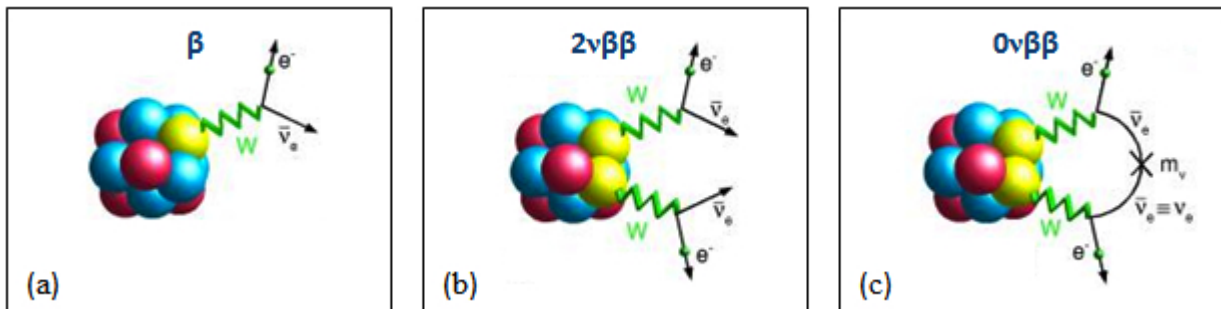


Figure 1 [1]

Under the Dirac Model, the expelled electrons and antineutrinos use the excess energy from the reaction to escape at high velocities, and because the reaction's energy is shared between the electron and the antineutrino, each can move with a large range of velocities. The electron's kinetic energy can be measured, and the range of its energies follows the large curve denoted " $\beta\beta 2\nu$ " in Figure 2. In the Majorana Model, however, the two antineutrinos, which can act as *each other's* antiparticles, effectively annihilate each other as the neutron decays, leaving the two escaping electrons with a fixed amount of energy. This fixed energy is represented by the small curve denoted " $\beta\beta 0\nu$ " in Figure 2. (Note: The smearing of the small curve is not a distribution of electron energies, but rather a product of the measurement's energy resolution, which is affected by background noise in the measurement.)

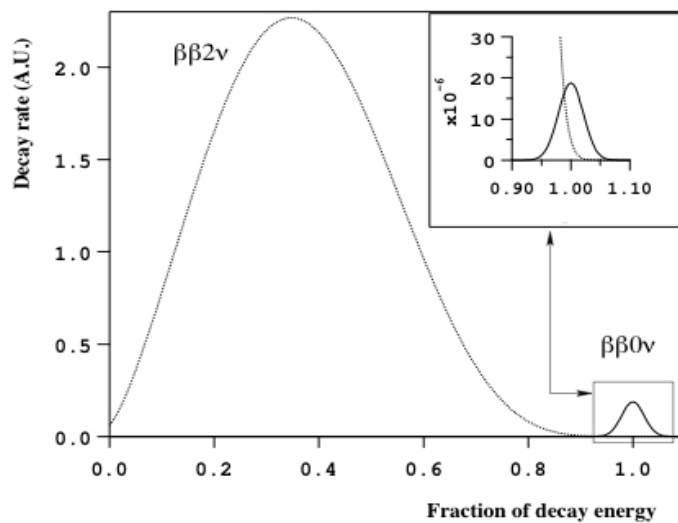


Figure 2 [2]

The CUORE project uses towers of crystals made of tellurium dioxide ( $\text{TeO}_2$ ) as its experimental source, since  $\text{TeO}_2$  is a well-known source of ordinary beta decay and is therefore a good candidate for producing neutrinoless double beta decay. The energies of the escaping electrons from decays are measured using the same source crystals as detectors. By measuring the electron energies of spontaneous decays within the  $\text{TeO}_2$  crystals, CUORE can determine the types of decays that occur and look for the signature electron escape energy of neutrinoless double beta decay.

### ***Three Towers Test***

During the summer of 2009, the CUORE Collaboration ran the Three Towers Test (TTT) as a diagnostic experiment to determine the most effective cleaning and preparation methods for reducing background radiation, which interferes with detecting the  $0\nu\beta\beta$  signal. This experiment was instrumental in the design of the final CUORE experiment, which is expected to start operation in 2013, as it helped the collaboration decide what cleaning method would remove the most background-causing contaminants from the surface of the crystals and their surrounding

structure. Cleaning/preparation methods tested on three crystal towers included (1) using a high energy ion plasma beam to remove impurities, (2) performing a thorough chemical cleansing of the copper framework and removal of crystal surface contaminants, and (3) wrapping all of the experimental components in thin, super clean plastic.

### ***Cooling System***

In order for the TeO<sub>2</sub> crystals to function as detectors, it is crucial that the crystals be kept at cryogenic temperatures to ensure a small specific heat. Following Eq. 2, a small specific heat corresponds to a large change in temperature for the electron energy deposited in the crystal.

$$\Delta E = mc\Delta T \quad \text{Eq. 2}$$

To get a large enough temperature increase to accurately measure the kinetic energy of an escaping electron, a crystal must have an extremely small specific heat. The specific heat necessary for electron energy detection can be achieved by keeping the crystals at a temperature on the order of 10mK. Therefore, CUORE is cryogenically cooled with a system that pumps liquid helium (LHe) around the crystal encasement structure.

This cooling system needs to be monitored and refilled with fresh liquid helium every other day in order to maintain the cold environment needed for electron energy detection, and rather than hire maintenance personnel to perform these tasks, the CUORE collaboration has made these tasks the shared responsibility of all collaboration members. Each member/institution of the collaboration is responsible for at least one week of refill shifts a year. During the late summer, however, it is particularly hard for the collaboration to find volunteers to perform shifts. First, late summer is vacation time for most people working in Italy, and as approximately two thirds of the collaboration is made up of Italian members, this greatly depletes the group of people available for shifts. Second, the rest of the collaboration is almost entirely made up of American members, and it is extremely hard for them to find the time to leave their regular jobs for a week and the money for a flight, hotel, and meals during the trip.

That is why my partner, Alison V. Goodsell, and I traveled to Assergi, Italy, under the supervision of our advisor and CUORE collaboration member, Dr. Thomas D. Gutierrez, in August of 2009 to perform three weeks of refill shifts at on the TTT experiment. We worked alongside other collaboration members experienced in the shift process to complete the tasks necessary to keep the cooling system working properly and the TTT experiment running smoothly. We learned that the refill process, while straightforward in its goal, is a good deal more complex than the simple concept of pouring in LHe until the experiment's cryostat is full. It included performing many tasks that had to follow a specific order, each executed in a precise manner, to keep the cooling system operating nominally.

## Refill Shifts

The refill shifts, which were performed every other day at the underground facility of the LNGS where the TTT experiment was located, involved three main tasks: working with the LHe recovery system, refilling the TTT main bath, and refilling the liquid nitrogen trap and evaporator for the TTT. A rigorous safety policy was followed during all refill shifts.

## Safety

The LNGS has employed many safety regulations in their underground facility, based on the working environment. All personnel entering the lab must wear proper footwear containing toe reinforcement and hardhats in case of falling material. Workers are also encouraged to wear long-leg pants rather than shorts or skirts. When working with CUORE experiments, people wear thick leather gloves whenever they handle equipment that could be exposed to the cold of LHe or liquid nitrogen (LN<sub>2</sub>).

Air supply is also a safety issue in a lab sitting a mile underground. If gas from an experiment or some other source were to enter the lab, there wouldn't be any way of venting it out, so it would displace the oxygen in any affected rooms, thereby making it a toxic environment. Because of this very real danger, the LNGS has created an extensive air safety plan for the lab that includes visual and audible alerts in case of a gas leak, portable breathing equipment in easily accessible places along the lab, and training for all personnel to instruct them on the proper protocol to follow in case of such an event. A typical breathing apparatus and visual alert are pictured in Figure 3.



Figure 3

### ***Liquid Helium Recovery System***

The LHe recovery system is shared between CUORE/TTT and the CRESST experiment at the lab to recycle used helium. LHe is extremely expensive, and it is fairly hard to transport large amounts to the lab's underground facility, so the CRESST experiment, which also uses LHe as a coolant, installed a recovery system to collect any used helium that has heated and become gaseous. Later, when CUORE entered the lab, they joined in to the recovery network to take advantage of the cost-effective system. The system is not able to collect and recycle all of the original helium, since it is impossible to completely seal all transfer connections and sometimes a little helium must be vented. Despite this fact, it is still much more cost effective to use this system and bring in a new tank of LHe from time to time to replenish the current LHe supply, than to use brand new LHe all the time.

A typical refill shift begins with a visit to the main hub of the recovery system (seen in Figure 4), where the collection balloon, liquefier, compressor, and empty and full transfer dewars are stored.



**Figure 4**

This is where all of the used helium is processed to put it in its proper liquid form. Used helium from both experiments is routed through transfer piping traveling the length of the underground lab and stored in the large collection balloon seen in Figure 5.





**Figure 5**

It is very important that this balloon does not inflate too much, as excess pressure on the balloon walls could cause it to rupture and all the used helium gas would be lost. Shift personnel are responsible for visually checking the balloon inflation throughout their shift to confirm a safe level of inflation. The balloon contains a good amount of helium gas in Figure 5, but the view of the balloon hanging over its base on the left side of the image suggests that the balloon is at a safe inflation level. Gas from the balloon is fed into the compressor where it is compressed to a much higher pressure to prepare it for the liquefier. A lab employee operates the liquefier and fills the transfer dewars as they are needed for each experiment.

When starting a shift, personnel must first collect a transfer dewar that has been filled with recycled LHe. The full dewar must be disconnected from the liquefier, and then the relief valve must be opened on the dewar before it can be rolled away. While this will allow a small portion of the helium gas in the top of the dewar to escape, the open valve is necessary to relieve any built-up pressure inside the dewar due to jostling of the fluid during transport. Once the full dewar is moved out of the way, a shift worker maneuvers one of the nearby empty dewars next to and connects it to the liquefier. Workers can determine the status of a dewar by the ID tag hanging around its neck, as seen in Figure 6. When the dewar is full, the ID tag is flipped to the blue “Full” side, and the date of the fill is written on the tag – “SAB 8” on the tag in Figure 6 stands for “Sabato 8” or Saturday on the 8<sup>th</sup> day of the month. When the dewar is empty, the tag is flipped to its red “Refill” side.



Figure 6

After the empty dewar is connected to the liquefier, a shift worker pushes a green button on the side of the compressor to initiate the compression/liquefaction process so that the system is ready for the lab employee to refill the empty dewars. Then the dewar is rolled through the halls of the lab to the CUORE/TTT experiment by two shift workers, shown in Figure 7.



**Figure 7**

Two workers are needed for the dewar transport in order to avoid jostling the fluid and causing a pressure spike inside. If the dewar is not handled carefully and a pressure spike were to occur, it could potentially explode, which would be extremely dangerous to any people and experimental equipment nearby.

Once the shift team reaches the CUORE/TTT experiment area, they roll the full dewar into the experiment's refill position. As soon as the dewar is stationary, the relief valve is closed to prevent more helium gas escaping from the dewar. At this time the recovery line should be connected to the dewar to make sure any gas trying to escape the dewar during the next portions of the process will instead be collected and contained in the recovery system's balloon. This connection can be seen in Figure 8, with the orange hose feeding any escaping helium gas back to the recovery system hub.

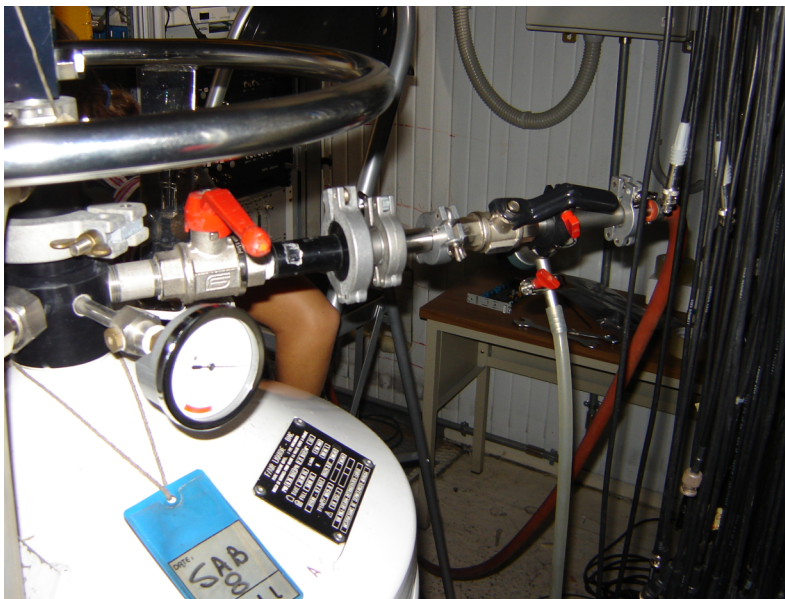


Figure 8

At this point, it is time to start the TTT main bath refill process.

### ***Main Bath Refill***

The first step in the refill process is to insert part of the transfer line into the LHe dewar. This part of the transfer line consists of a piece of metal tubing hardware commonly called a T-line that hangs from a ceiling pulley. Two people are absolutely necessary for this step, though three are preferred. One person must operate the chain pulley system that lowers the T-line into the dewar, while another stands on a ladder above the dewar to direct and guide the T-line through a narrow valve on top of the dewar. A third person monitors the dewar's pressure, and he/she can also assist the person on the ladder in guiding the T-line straight down into the dewar. Figure 9 shows the pulley chain and dewar T-line valve (left), a T-line (middle), and the dewar pressure gauge (right).



Figure 9

It is very important that the T-line be inserted completely vertical, otherwise the thin metal of the T-line tubing can easily experience bending or kinking so that the T-line won't properly insert into the dewar. At the same time, it's also important to insert the T-line slowly (approximately a couple inches every 30 seconds) and monitor the dewar pressure closely, because the action of inserting a T-line at room temperature into the dewar at cryogenic temperatures can cause immediate pressure spikes in the dewar. As mentioned in the recovery system section above, pressure spikes are quite dangerous, and in this case the pressure should never exceed 400 mbar; if the pressure rises above 300 mbar during the insertion process, the crew pauses until the pressure decreases to a safe level. The need to accomplish all of these tasks simultaneously makes 3-person shift teams desirable, as there is a third person who can be solely responsible for monitoring this pressure gauge as well be available to help the other two shift personnel if a complication arises.

Once the T-line is inserted to the appropriate depth, the vacuum transfer hose (seen in Figure 10) is connected to the top of the T-line. The LHe will soon start flowing along the transfer line, so to stop the loss of LHe to the recovery system, the recovery valve is closed.

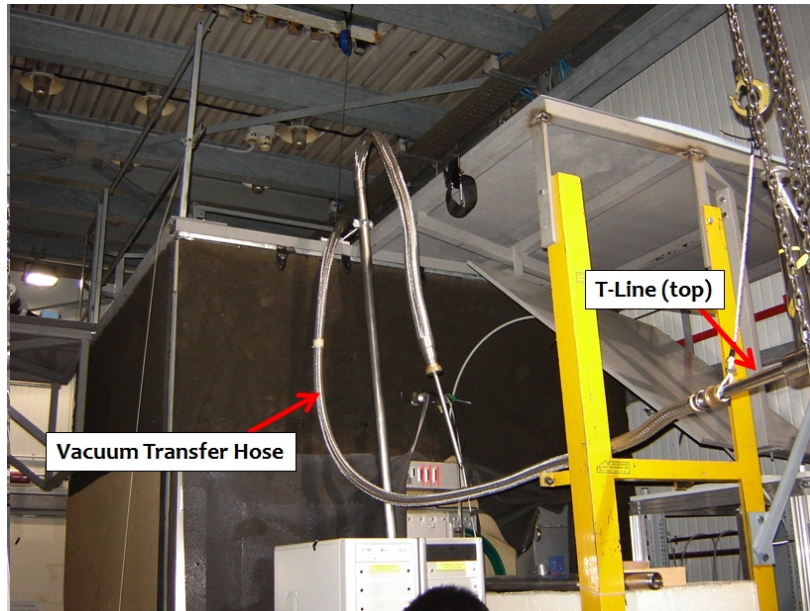


Figure 10

Now focus moves over to the experiment's cryostat and its surrounding structure. One person enters the structure, called a faraday cage, from an access door at the bottom and climbs up inside while another person climbs a ladder outside to stand on top of the faraday cage. Figure 11 shows the door (left), the view from inside the faraday cage (middle), and a view from outside looking at the top of the cage structure (right).

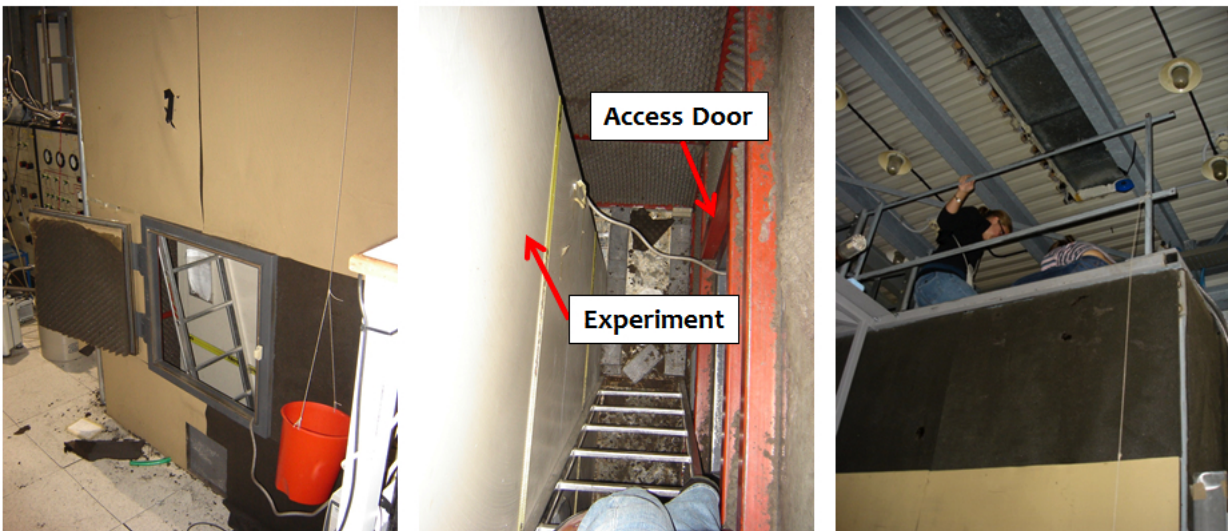


Figure 11

The person on top feeds the T-line through the opening at the top of the faraday cage, and the person inside helps guide the line to the cryostat fill valve. He/she then quickly opens the valve and immediately inserts the T-line an inch or so to prevent the LHe inside from evaporating and

escaping from the cooling system. The views from the top of the faraday cage and inside the cage during this process are shown in Figure 12.

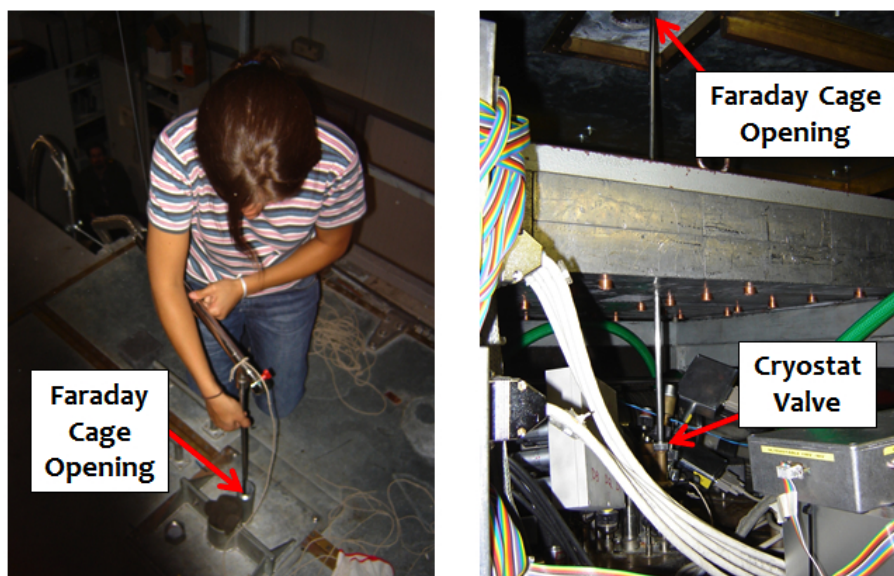


Figure 12

Now that the upper T-line is in place on top of the faraday cage, the transfer line can be connected between the refill dewar and the experiment. A shift worker next to the refill dewar opens the valve to allow helium to flow up through the vacuum hose. At the same time, the person on top of the experiment holds the other, open end of the vacuum hose in one hand and directs the opening toward their other hand. This is fine because the helium flowing through is initially gaseous and warms up some as it travels, since the hose is still mostly at room temperature. When he/she feels the gas flow coming out of the hose, he/she securely inserts the hose end into the T-line. At this point the whole transfer line is connected, and all that is left for the transfer to start is to insert the upper T-line fully into the cryostat. This process takes roughly 15-20 minutes, as the person on top of the faraday cage must push the T-line in 2-3 inches at a time and waiting roughly a minute between pushes. This is similar to the T-line insertion into the dewar – it's necessary to go slow to avoid causing a pressure increase in the cryostat, since the T-line is initially so much warmer than the cryostat.

When the T-line has been fully inserted and the cryostat valve has been tightened around it as much as possible, pure pressurized helium gas from a storage tank (seen in Figure 13) is connected to the dewar to augment its pressure. Once the transfer starts and the line cools down from the LHe flow, the pressure inside the dewar can be increased via the pure helium tank to approximately 250 mbar. This will help force the flow of LHe up the transfer line and into the cryostat. During the transfer, which runs for roughly an hour, the dewar pressure should be

maintained in the range of 200-300 mbar using small bursts of pure helium gas from the storage tank.



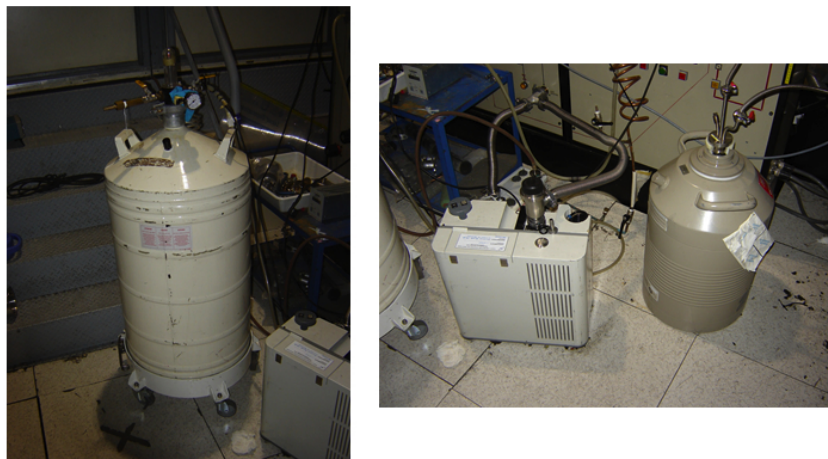
**Figure 13**

During the refill, measurements are stopped and the computer monitors the main bath level. When everything is running smoothly, workers still need to periodically check the system, but other than that, they have roughly an hour of down time between the start and end of a transfer. To take advantage of this free time, shift personnel perform smaller LN2 refills on some of the other experimental equipment during the main bath refill.

### ***Liquid Nitrogen Refill***

In addition to the main experiment's cooling system, which uses LHe as its coolant, there are also the nitrogen trap and evaporator that are also part of the cooling system. Pictures of the trap (right) and evaporator (left) are shown in Figure 14. The trap's job is to condense any contaminant gas, such as water vapor and carbon dioxide, out of the gaseous helium part of the cooling system. This works because the contaminants return to their solid state at LN2 temperatures, but helium condenses at much lower temperatures, and so the solid contaminants will fall out of the helium gas. The evaporator is responsible for "flushing the cryostat with nitrogen gas to prevent radon contamination" [3].





**Figure 14**

This equipment must be refilled at the same time as the main cooling system. Once the main bath refill is running smoothly on its own, the shift personnel will attend to the refilling of these two LN2 dewars. They take a small 10-liter dewar and thick leather gloves from the experimental room and walk to a large LN2 dewar down the hall of the underground lab. Here they fill up the small dewar to take back to the experiment. Below Alison can be seen refilling the small dewar in Figure 15.

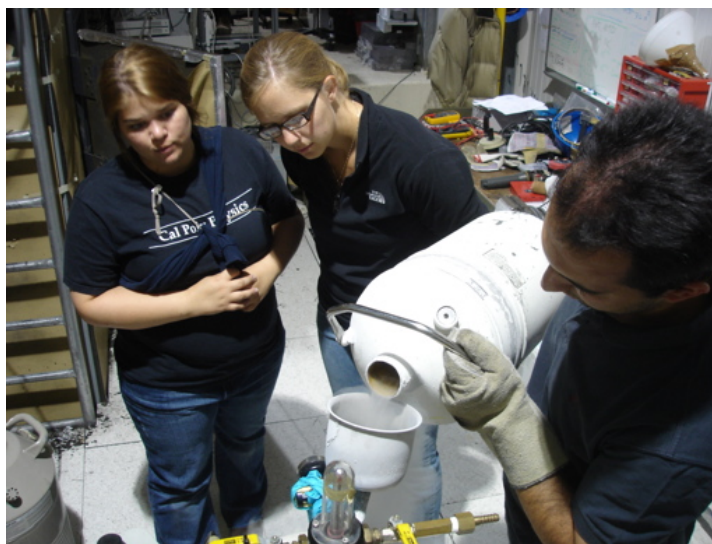


**Figure 15**

The LN2 is not as expensive to replenish as LHe, so it isn't necessary to have an extensive recovery system for LN2 use. The typical protocol for LN2 dewar filling is to "top it off," or to fill a container until it overflows slightly. This isn't dangerous, as the overflowing LN2 will

quickly evaporate. The nitrogen gas that flows over the ground is, however, quite cold; this is one of many reasons workers are encouraged to wear long pants and warm socks.

Once the small dewar is full, the workers walk it back to the experiment and begin the trap refill. This refill is fairly straightforward, with one worker opening the cover on the trap's top opening slightly and holding a specially shaped funnel in opening while another worker carefully pours LN<sub>2</sub> from the small dewar into the funnel. The trap is filled so it just starts to overflow, and then the workers move on to refilling the evaporator. This is a little bit more difficult, as there is special measuring equipment inserted through the evaporator's top opening, and the funnel must be inserted into the opening next to all of this measuring equipment. Sometimes it will take the workers a couple tries to insert the funnel far enough to refill the evaporator properly. Once the funnel is in, the workers repeat the same pouring process as what's used on the trap. Alison and I can be seen observing an expert shifter, Luca, perform the refill on the evaporator in Figure 16.



**Figure 16**

The evaporator is also filled to slightly overflowing, and then the small dewar, the special funnel, and the thick leather gloves are placed in a storage area in the experimental area to be out of the way in between refill shifts. After this is finished, the shift workers can go back to monitoring the main bath refill and waiting for it to finish.

### ***Shift Conclusion***

When it reaches approximately 100%, the cryostat is full, meaning the refill is over and the transfer line must be dismantled. The transfer is first cut off at the dewar by closing the dewar's vacuum hose connection valve. The recovery valve is immediately opened again to avoid any loss of helium gas from the dewar. The pure helium gas tank is also disconnected from the dewar at this time. The vacuum hose is disconnected first from the upper T-line on top of the faraday cage, and then from the dewar T-line.

The upper T-line is then removed from the cryostat. Unlike the insertion process, the line is pulled out very quickly from above the cage while another person inside the cage is ready to plug the cryostat valve as soon as the T-line is removed – this is yet another attempt to avoid evaporation and loss of helium inside the cryostat. Finally the dewar T-line is removed quickly using the pulley system while also being guided out by hand, and the line valve is plugged up immediately following the line's removal. As all the metal lines are being removed by hand, the workers make sure to wear their protective gloves, since the T-line tubing coming out of the cryostat and dewar have been cooled to tremendously cold temperatures that can cause severe burns.

## Acknowledgements

Thank you to Alison V. Goodsell and Dr. Thomas D. Gutierrez for allowing the use of their photographs. Thank you to Alison for her literary contributions. Thank you to Thomas for his continued help and advice on this project.

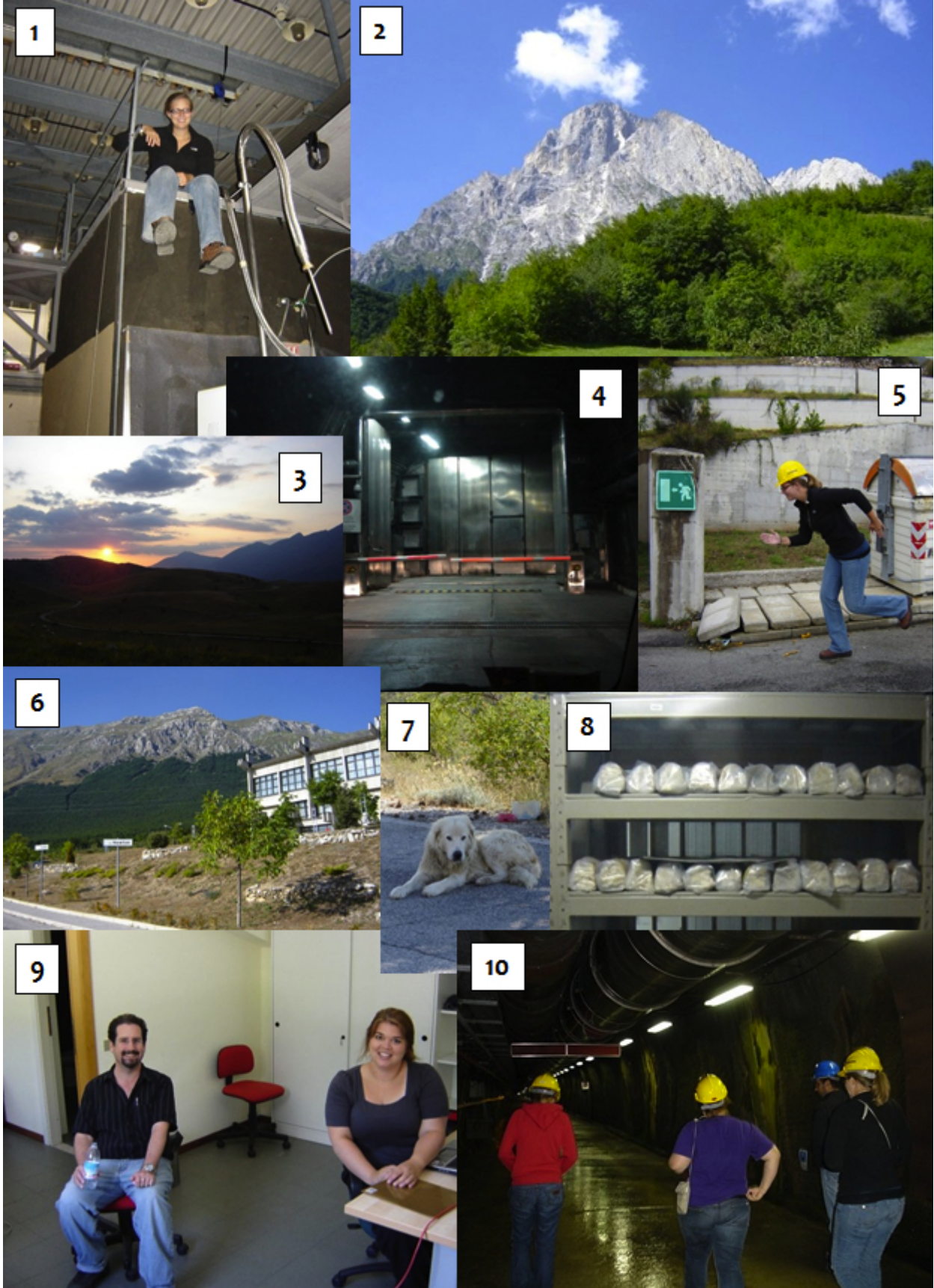
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## **Appendix A: Photo Collection of Project Experience**

The collection of photos below expresses some of our memories from the experience of working on the CUORE project. Descriptions of the pictures are also listed below.

1. Myself atop the faraday cage that houses the TTT experiment.
2. The view of the Gran Sasso mountain range seen from the highway just before entering the 10 km highway tunnel that provides access to the underground lab facility.
3. Sunset view from a back road on the mountain range.
4. The large folding metal doors of the main underground lab entrance.
5. Myself imitating one of the emergency action signs at the above-ground lab facility.
6. A view of the above-ground lab facility with the Gran Sasso mountain range behind.
7. One of the many wild dogs living near the lab would sit at the above-ground lab entrance all day, every day. He was nicknamed Bob the Lab Dog.
8. Molds of raw lead that were recently recovered from a sunken Roman ship dating back over 2000 years. This lead is melted down and used as the main shielding for the CUORE experiment.
9. Thomas and Alison in our office in the above-ground lab. We would work in this space when we weren't performing shifts underground.
10. Alison and myself walking through one of the underground lab tunnels with two Italian shift personnel, Lucia and Luca.



## **Appendix B: Neutrino Research at Gran Sasso National Laboratory 2009 Trip Reports**

A website was created by 2009 Central Coast Astronomical Society President, Walter Reil (my father), as a posting board for trip reports written by myself, Alison Goodsell, and Dr. Thomas Gutierrez. The website, <http://www.fix.net/wreil/Gran-Sasso-Trip.htm>, will not be supported online for much longer, so its contents are displayed in this appendix as a permanent record. Reports are listed from newest to oldest.



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Neutrino Research at Gran Sasso National Laboratory  
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**Last Status Report posted: [Report 15, Tuesday, September 15th](#)  
Final trip report from Ali Goodsell  
Go to [Status Reports](#)**

This non-Cal Poly website is provided as a courtesy for Cal Poly Physics by [Walter Reil](#)

This website and series of status reports is presented for folks who are interested in science, technology, engineering and mathematics (STEM) education, the study of our universe, foreign travel and enjoying something fascinating, energizing and uplifting happening during August 2009 in Italy ([NASA satellite photo](#)) involving [California Polytechnic State University San Luis Obispo](#) students. Here is an opportunity to experience cutting-edge physics research by local college students on the other side of the Earth, far from San Luis Obispo County.

[Cal Poly Physics](#) senior's [Robin Reil](#) (Atascadero, CA) and [Ali Goodsell](#) (Mountain View, CA) spent the month of August 2009 working as research interns at the [Gran Sasso National Laboratory \(LNGS\)](#) in [Assergi, Italy](#), 75 miles east of Rome. LNGS is the world's largest underground particle physics and nuclear astrophysics research facility 4,600 feet beneath the Gran Sasso Mountain ([photo](#)). Robin and Ali are supporting [neutrino](#) energy research involved in the [Cryogenic Underground Observatory for Rare Events \(CUORE\)](#) project.

Cal Poly Physics Professor [Dr. Thomas Gutierrez](#) accompanied them the first week to get them settled at the facility and perform research related activities. Tom is the lead research scientist on this project for Cal Poly, having made numerous trips to LNGS in past years with prior students who also supported this research work. Cal Poly's involvement in supporting this research work began in 2007.

Funding for this project is provided by the [National Science Foundation](#).





[Ali Goodsell - Robin Reil - Tom Gutierrez](#)



[Gran Sasso National Laboratory](#)

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See the [Photo Gallery](#) for photos from 2007, 2008 and 2009 Cal Poly trips.  
Links to pre-Cal Poly Gran Sasso photos are also provided.

This website provides insight into the August 2009 trip, neutrino research, and other activities that Tom, Robin and Ali experienced during this adventure. The foundation for this reporting is information provided by the team via occasional email reports and Skype video chats.

[Top Of Page](#)

Header image of galaxy NGC 891 by [Johannes Schedler](#) at [Panther Observatory](#), Austria

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**Status Report 15, Tuesday, September 15, 2009**

By Alison Goodsell  
Monday, September 14, 12:29 PM

No new photos posted at this time

Another summer internship at the Gran Sasso National Laboratory is over. And as last summer, it was a fantastic experience due to the scientific work completed, the relationships renewed and created, and the adventure innate to Italian living. This incredible opportunity offered by Dr. Thomas Gutierrez through his work for the CUORE Collaboration completely transformed my college career and my future work expectations.

The work Robin and I were involved with this summer greatly differed from last summer. It's hard to even compare the experiences! But I suppose that is what makes this work so incredible – the varied work options available. Last summer, Laura Sparks and I were mainly above ground working on the decontamination of the tellurium dioxide crystals and the copper framework. We were often sequestered in a clean room, fully suited up in the 'white bunny suit' – a fully body clean suit jumper with hood, booties and face mask. Removing the surface contaminants from the crystals was hard work, as we wet-sanded each of the 6 crystal faces. It was a constant process of sand, wash, dry, weigh and repeat. Each crystal took upwards of two hours, and we cleaned 24 crystals! But Laura and I established a rhythm and found both pleasure and a feeling of accomplishment from completing this work intensive task.

Robin and I did not focus on decontamination this summer. Instead we had the important (and required!) job of keeping the current CUORE experiment, the Three Towers Test, operational. We were constantly underground refilling the Liquid Helium refrigeration system. This process was also work intensive as we lugged heavy dewars through the tunnels, poured gallons of Liquid Nitrogen and climbed on top of the cryostat. During each shift, I learned more about the experimental process. From perfecting how long it took to fill a Liquid Nitrogen dewar to interpreting the level of inflation of the Liquid Helium compressor balloon.

I am also extremely grateful for the international work experience Tom's internship provided. How often do undergraduates have the chance to travel to a foreign country, work in a nuclear physics research laboratory and form relationships with scientists from all over the world? Not very often! Throughout college I have always tried to take advantage of the opportunities offered by Cal Poly and other research institutions. I feel that everything about this experience, from the work to the conferences and posters sessions, has opened up my eyes to all the scientific community has to offer. And I am very happy to say, it offers a lot!

Fortunately, Robin and I were given some time to explore Europe after our work was finished at Gran Sasso. (Another awesome benefit of working for Tom!) We traveled to Switzerland and France to tour CERN, the high energy circular collider, and Geneva. We were very lucky as two of Dr. Jennifer Klay's students were working at CERN and gave us a behind-the-scenes tour of their experiment, ALICE.

Summers like this make me realize just how incredibly fortunate I am to have professors and a school like Cal Poly that provide these opportunities. Not many institutions so thoroughly involve their undergraduate students in cutting edge research. I am so lucky to have two summers of nuclear physics research experience before I even apply to graduate school. And due to my successful research opportunities which always remind me how much I love experimental science, I guarantee I am going to continue my education in nuclear science.

Alison Goodsell

[Top Of Page](#)

## **Status Report 14, Friday, September 4, 2009**

By Walt Reil  
Friday, September 4, 5:00 AM

No new photos

The August 2009 Cal Poly Physics Gran Sasso research trip is now complete. As planned, Robin and Ali returned safely to California last night. Now for much-deserved R&R over the next couple weeks before the fall session of classes gets underway at Cal Poly.

Stay tuned for a possible trip wrap-up status report and maybe more photos.

Walt

[Top Of Page](#)

## **Status Report 13, Wednesday, September 2, 2009**

By Walt Reil  
Wednesday, September 2, 5:00 AM

No new photos

Robin and Ali are on their way back to the U.S. Today they are flying from Geneva, Switzerland, to Rome, Italy, where they will spend the night near Rome's airport then fly back to the U.S. on Thursday, arriving back in California around midnight.

Walt

## Status Report 12, Sunday, August 30, 2009

By Walt Reil  
Sunday, August 30, 5:30 PM

### NEW PHOTOS

A plethora of new photos have been added to the [Photo Gallery](#). Several new photos were added to the Lab photo display and Local Area display. And, two new display web pages have been added devoted to Robin's and Ali's outstanding visit to Rome.

We had another Skye video chat with Robin and Ali this morning. They are doing fine. Today they traveled around their small village of Saint-Genis-Pouilly and visited the above-ground Large Hadron Collider [ALICE](#) project facility and were able to look down the huge vertical access shaft to the LHC tunnel below.

Tomorrow, Monday, will be their day to visit CERN and its visitor center to pick up memorabilia.

Walt

[Top Of Page](#)

## Status Report 11, Saturday, August 29, 2009

By Walt Reil  
Saturday, August 29, 10:55 AM

No new photos yet

My wife Julie and I just finished a Skype video chat with Robin and Ali using Robin's Mac laptop. Ali was also video chatting with her mother on Ali's laptop. Chatting was a challenge due to choppy Internet connections.

They have arrived safely in [Saint-Genis-Pouilly, France \(photo\)](#), just across the border from [Geneva, Switzerland \(photo\)](#) taking a 1.5-hour jet flight from Rome to Geneva aboard [Baboo Airline \(photo\)](#). They loved the flight sitting in comfortable leather seats. They received many free and delicious things to eat, all totally unexpected and very enjoyable. They felt like kids in a candy store.

They spent a marvelous day yesterday, Friday, in Rome, including visiting [Piazza del Popolo \(photo\)](#), [Villa Borghese \(photo\)](#) and [Villa Borghese Gardens \(photo\)](#), [Vatican City](#), [St. Peter's Square \(photo\)](#), [St. Peter's Basilica \(photo, photo\)](#) and the [Roman Coliseum \(photo\)](#), traveling around the city via the Metro (subway) and a lot of walking. It was a VERY HOT and HUMID day. Ugghhh!

Travel from Geneva to Saint-Genis-Pouilly was a bit of a challenge, kind of getting off-track via the bus system (going the wrong way), but it turned out just fine, as they just happened to get a nice unexpected bus tour of the area, passing by the [Palace of Nations \(United Nations \(photo\)\)](#), so they will definitely be making a trip to visit that premier attraction.

The rest of today and tomorrow will be spent on impromptu exploration of Saint-Genis-Pouilly and Geneva, seeing whatever they can. It is possible they will be accompanied by two other Cal Poly Physics students (guys) who have been working at CERN, under the direction of Tom Gutierrez's wife Jennifer who is working on

the [ALICE](#) ([photo](#), [photo](#), [diagram](#)) project at the [Large Hadron Collider](#) ([photo](#), [photo](#)), but the guys will be leaving for SLO on Monday. Jennifer is already back in SLO.

Monday will be their day visiting [CERN](#) ([photo](#)).

By the way, the several-day trip and visit to Geneva and back to Rome is totally on their dime, covering the costs themselves.

That's all for this update.

Walt

[Top Of Page](#)

## Status Report 10, Thursday, August 27, 2009

By Walt Reil  
Thursday, August 27, 10:50 PM

No new photos yet

This morning Robin and Ali completed their work duties at the lab. This afternoon they obtained a ride to L'Aquila where they were to catch a bus to Rome where they would spend the night in a hostel. They will spend all day Friday touring Rome. On Saturday they will fly to Geneva, Switzerland, to spend a few days touring some of France and Switzerland and hopefully visiting [CERN](#), the European Organization for Nuclear Research, and its [Large Hadron Collider](#).

[Top Of Page](#)

## Status Report 9, Thursday, August 20, 2009

By Robin Reil  
Thursday, August 20, 5:50 AM

We are getting a lot more comfortable with the shifts. We've done it enough times that, assuming everything goes smoothly, we generally know what to do without checking the manual. We haven't yet checked about the auditorium. Ali says she doesn't think there is one, but there is a part of one big building toward the front of the lab that we haven't seen yet. There is a big library, though.

To do the shifts, we were given a couple manuals in PDF form that describe the shift process and give numbered instructions. We were told (and are still reminded, though we usually remember on our own) about the general safety measures - mainly to wear hard hats when not in the experimental room, and when we're handling anything that could be cold due to the liquid helium or nitrogen (like the metal transfer lines we actually insert into the liquid helium) we wear leather or thick rubber gloves to prevent the burning of our skin.

Outside the metal door that is the access point to the underground lab from the highway tunnel, there is an intercom pad where you drive up, push the button, and when they say "Si?" you give them information about the project you are working on. There is also a camera that can view the whole front of the car, including the front license plate and the windshield. I'm guessing the guards right inside the metal door check the video feed to make sure they recognize someone in the car.

I have not had my official safety training yet. That happens on Monday. That is why I have to be escorted by

someone with a badge (that includes Ali and EVERYONE else here), so if something happens they can be in charge of me. Generally what I have seen is that there are fire alarms located all over the place underground, and there are tons of masks with oxygen tanks in special boxes all along the walls in case there is smoke from a fire or if there is a lack of oxygen in the tunnel. There are also those signs all around with a message can change. You have a picture posted of one of them that I took - it normally just says "INFN - Laboratori Nazionali del Gran Sasso" in red electronic letters. Those are all over the place, and in the case that there is a gas leak which would cause the oxygen in the tunnel to be displaced, I think there is an alarm (probably with flashing lights and sound) that goes off and those signs start flashing the message "OXYGEN DEFICIENCY" in Italian and English so everyone knows to go put a mask on. I am not 100% sure this is exactly how it happens, since I haven't been trained and I haven't experienced an emergency situation like this, but I imagine this is probably pretty close to what happens. In a situation like this, you must evacuate, so you go to whichever of the two exits is closest and you enter the highway tunnel. There is a large area of space next to both exits where no cars drive so that people from the lab can safely exit without getting run over by cars. The speed limit in the tunnel is around 130 kph (a little over 80 mph), but a lot of drivers go faster, around 150 kph (about 93 mph), and there is normally no emergency lane in the tunnel, so this extra space for people to escape the lab tunnel is very necessary.

Robin

Top Of Page

## Status Report 8, Tuesday, August 18, 2009

By Professor Tom Gutierrez  
Tuesday, August 18, 12:37 PM

It is good to be home with my family, but the latest trip to the LNGS with Ali and Robin was definitely productive. My primary task on this short trip was to acclimate them to life in Italy (and the LNGS) and to ensure they had underground access. I also wanted to make sure that the lodging, food, money, transportation, and communication arrangements were in place. I then assisted in training them to perform shifts for the Three Towers Test (TTT).

As part of the membership criteria of the collaboration, each member institution must provide a designated number of weeks of shifts per year at the LNGS. This can vary year-to-year depending on the collaboration's needs. For example, last summer (2008) there was no experiment running in the summer, and no shifts were required. Service to the collaboration was spent (with Ali and Laura) performing other non-shift activities such as preparing crystals and testing copper cleaning methods. This summer, our group, in addition to performing the requisite Cal Poly shifts, is also covering for another university to help them maintain a reasonable travel schedule this summer.

The standard shift typically consists of one expert shifter and one rookie shifter both going underground ("La Galleria") once every other day (but sometimes more frequently if things aren't running smoothly). The primary task of the rookie shifter is to assist the expert shifter in refilling the main bath of the cryostat with liquid helium, refilling the evaporator and trap with liquid nitrogen, starting and stopping the data acquisition system, transferring data to Milan, Italy, moving tanks to and from the helium liquefier, and assisting the expert shifter in any other activities necessary to keep the data flowing. Rookie shifters can also be "on call" to assist with any set of similar activities in Hall C, where CUORE research and development is taking place. While this sounds like a straightforward checklist (indeed, the basic tasks of the rookie shift can be learned in less than a week on-the-job), there is always something non-standard about the "standard shift". O-rings break causing liquid helium losses, ice gets trapped in the transfer lines slowing or stopping the helium transfer, the 1K pot evaporates too quickly and various valves must be fine-tuned, or perhaps unexplained noise emerges in the electronics (during one diagnostic test several years ago, we were able to measure the temperature rise of the

\*telephone ringing\* because of a faulty ground loop, which had to be fixed immediately -- that's how sensitive the experiment is). It is also important to check the prior data run for anomalies and confirm the liquefier's reclamation system doesn't become overfilled with helium gas, etc. All of these things must be resolved real-time before the day's shift is over, and it is the job of the expert shifter to troubleshoot these issues and direct the rookie shifter.

The day before I left, the students were given an assignment by Paolo. They needed to calculate how much potassium chloride would be required to make a potassium-40 source with a very specific activity (decays per second) for only one of the gamma lines (1460 keV), which is part of potassium-40's electron capture process to stable argon. After calculating it, they will now go into the chemical lab and actually make this source to be used as a calibration for the TTT. These are not dangerous "hot" sources by ordinary standards, since the potassium in the potassium chloride was natural. That is, it is literally as radioactive as a banana. But for an experiment designed to measure very rare decay processes, even the tiny natural radioactivity in off-the-shelf potassium is "hot" enough to be used as a calibration source. All of us independently worked out the calculation and compared our numbers, confirming the solution: a sophomore level homework problem put into action.

In addition to all of the LNGS activities, I have also given Ali and Robin some tasks to generate computer simulations for the CUORE experiment using the powerful [GEANT4](#) package. GEANT4 is a customizable open source software tool designed to accurately model the passage of radiation through matter, and is an industry standard in nuclear and particle physics. Not unlike an elaborate computer game, a detailed 3D geometry of the detector is created (including all materials used). Radiation is then allowed to interact with the detector in a realistic way, consistent with a host of various user-defined parameters. The GEANT4 application for CUORE was created by our Livermore collaborators and we are using it at Cal Poly to try and explore future directions of the CUORE experiment.

I will arrange a semi-weekly Skype call with Ali and Robin to check on their progress and well being, otherwise they are on their own until they return to the States in early September. Like in previous years, it was delightful spending time with my students as well as my friends and colleagues at the LNGS. I look forward to the next adventure.

In the mean time, reality calls and I have to organize the bills for this trip, prepare classes for the fall, tidy up some other summer physics projects, and finish organizing a proposal for my next round of funding. But I never forget that it is a privilege to be part of the CUORE collaboration and that I have the opportunity, through generous support of the NSF, to expose undergraduates to this cutting-edge science -- especially during such an exciting time in neutrino physics.

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[Top Of Page](#)

## Status Report 7, Tuesday, August 18, 2009

By Robin Reil  
Tuesday, August 18, 7:43 AM

We got a day off on Sunday, so Iulian and his friends took us to the [Adriatic Sea](#). We went to [Roseto degli](#)

[Abruzzi](#), a beach town, and just hung out on the HOT sand and in the beautiful water for a couple hours. The water is a lot warmer than the Pacific Ocean - I think it might have been slightly warmer than the pool at our hotel (it's not heated). And the sea is way salty, so you can float really easily. Plus, the beach drops really gradually into the water, so no large waves form and you can walk out for quite a while before you can't touch the bottom anymore. It was so nice, I think Ali and I spent at least 4 of our 5 hours in the water, mainly just floating. That night we went out for a really good dinner with Luca 2.0 (who we now know is Luca Pattavina) in Assergi.

Remember how I mentioned that on Saturday we had a HUGE lunch? That was because of the Italian holiday called [Ferragosto](#), when everyone celebrates by having meals that last for hours (ours was 3 hours, but it would have been at least 4 if we hadn't skipped a course and if we had wine like we were supposed to). The dinner we had Sunday night was also large, but not as large - just antipasti (I had formaggio, primo (pasta), and dessert. We also had a good deal of wine, and Luca had us try some drinks I would classify as after-dinner liqueurs. We tried 3, but I only remember the name of one, Limoncello, which was very good - it's Luca's favorite.

Yesterday (Monday) we did a shift that went very smoothly. We had dinner with Luca, Marco, and Kiara down in [Paganica](#) at a restaurant Luca and Marco always visit when at Gran Sasso. Kiara is our expert shifter for this next week (our last week), and Marco came from Milano ([Milan](#)) for a couple days to do some high-precision measurements on the experiment. Ali, Luca, and I had [bruschetta](#) (pronounced bru-sketta - ch has a hard k sound in Italian) for antipasti, and it was really good and yet it seems simple to make. I might make some for you when I get back.

Today we repackaged some samples of KCl (potassium chloride) to use as pulse sources for the experiment. I'm guessing we will be helping to insert them into the experiment underground at some point, if we can figure out how to securely attach them to a thin copper wire cable before we leave.

Ok, I need to get some stuff done before I head out to catch the bus back to Fonte Cerreto.

Oh, we found out that since the earthquake, the bus system all the way from Paganica up to Fonte Cerreto is free, so I think we won't have to spend much, if anything, on transportation while we're here (except of course the bus to Rome, and transportation in France/Switzerland, but we're paying for that).

I hope life is going well in the U.S.

Robin

Top Of Page

## Status Report 6, Friday, August 14, 2009

By Robin Reil  
Friday, August 14, 1:54 AM

Yesterday we went underground to do our first real shift. It went a little long, since one of the O-rings broke on the transfer line after we had gotten everything hooked up, so we had to take it all apart and start again with a new O-ring. But overall it went well. We also prepared some samples of potassium chloride that we'll put inside the experiment next week. They will be used along with a pulse source that's already in the experiment to make sure the experiment stays pretty well-calibrated between calibration runs.

It sounds like it's really hot there in Atascadero. I'm glad that it's starting to cool off a little bit here. It hasn't been THAT hot, but our room can tend to get pretty warm. We are also happy that our window has this grate



thing that comes down through the wall to cover the window in a way that allows air to come through but keeps the big bugs outside. Plus we have our fan now, so we keep that on whenever we're in the room and it keeps our sleeping area cool. Your mention of Wendy doing laundry reminds me that Ali and I will need to find a way to do laundry sometime soon.

We're planning to go to Rome the day before we fly to Switzerland. We'll take the bus in Friday morning (Aug. 28) and get there around noon, at which point we'll drop off our luggage at our hostel (which we booked last night). We're looking into our options of things to visit, since we'll only have 1 day, so we really can only visit one big place. I suggested [Vatican City](#) and also [Castel Sant'Angelo](#), and Ali wants to see the [Villa Borghese](#), a large garden area that also has some museums. We'll make a decision sometime soon about what we'll go see. Then Saturday morning we'll get to the airport by about 8:30 am so we can store our luggage and go through security before our flight at 10:50 am.

We might go to the [Adriatic Sea](#) on Sunday if Iulian and his fiancée Claudia want to take us. We went to their house in [Teramo](#) Wednesday night for dinner, and they were really cool. She told me and Ali that she would talk to Iulian and see if he would take us all to the Adriatic this weekend, so we're hopeful. Iulian gets along well with us, which I'm guessing has to do with the fact that he is actually a post-doc from South Carolina. He was doing his Ph. D. in Romania (where he's originally from) when a professor from South Carolina visited and gave some talks at his school. He met the guy, who told him he should come check out his school in the U.S., and long story short, he ended up doing school there. He was actually in the U.S. when the earthquake hit here in L'Aquila. He and Claudia were living in L'Aquila then, so she was in their apartment when it happened, and she was stuck out in the cold for about a week. The earthquake happened the night before he had a big interview for a job, and he didn't get any sleep since Claudia had called him about the earthquake. He also had been driving for 2 days straight before that to get to the job interview site, so he was running on fumes, which apparently showed in his interview - he didn't get the job. Claudia also gets along well with us; she enjoys speaking English with us (she wants to get better at it), and I think she really wants to visit the U.S. She and I also share a fondness for shopping, so she told me about some of the good shopping in the area. I hope we'll have an opportunity to hang with them a few more times before we head off to Switzerland, France, and then home.

I don't know if we'll get to go up to the top of the Funivia (gondola), an area called [Campo Imperatore](#), to see the observatory, Observatorio Astronomico. We definitely need a car to do it, so we'd be at the mercy of either Iulian or possibly our expert shifter Luca 2.0, both of whom have cars. We might consider asking them if they'd be interested in taking us, but I'm not going to get my hopes up on that one.

Robin

Top Of Page

## Status Report 5, Monday, August 10, 2009

By Robin Reil  
Monday, August 10, 2:36 PM

Tomorrow (Tuesday) we're going underground again for another shift, and we will be working with our new expert shifter, Luca 2.0 (our nickname for him since the guy currently doing it is also Luca). He got here today and tomorrow the two Lucases will go down together so that Luca 2.0 can get up to speed and take over responsibility.

Some things I wanted to clarify, as Tom explained some things to me.

1) I thought I had heard that a lot of the local restaurants made their own house wines, and it turns out I am

probably wrong about that. While it's possible a few have their own, it's much more likely that they serve a local wine from the [Abruzzo](#) area as their house wine. So it is still unique to the area, but not made by each individual restaurant.

2) Paolo and Iulian are not in charge of the Americans. Both of them are largely involved in CUORE, but their involvement with us is more specifically due to the fact that Tom has come to know both of them pretty well in his past years of working on the project. As I said, Paolo is kind of in charge of us (the students from Cal Poly), but that is because Tom and he have a personal relationship and Tom has asked Paolo to help us get involved with the project in more hands-on ways than would normally be expected of visiting undergraduate students. Paolo helped get last year's student team to get involved with the crystal lapping and the testing for copper contamination cleaning methods. Paolo lectured to us for a bit today to help us understand the point of the experiment we are working shifts on - the [Three Towers Test \(TTT\)](#).

3) I was also wrong about that project in the sense that I told you previously that there are 3 towers located at different labs running tests to determine which is the best design. It turns out all three towers are at Gran Sasso, and all inside the chamber at which we do our shifts. Each tower has identical components as far as the crystals and copper framework are concerned, but each tower has been decontaminated (or the contamination on the tower has been "contained") using a different approach. The CUORE collaboration is running the test on TTT to determine the best decontamination process - the best is generally the one that gives the smallest background signal (I think - I'll ask Tom about that).

4) I also learned that there is another intermediate step before CUORE itself is built and set into operation. There will be a predecessor called CUORE-Zero, which will be a test with one tower of crystals built according to the CUORE design that will be placed in the new holding area that will eventually house CUORE. It's like a trial run of CUORE with just one tower rather than all 19.

As I said, today we learned about the purpose of the TTT. We learned some of the physics behind it, which is very complex with lots of analytical mathematics as well as modeling and so much more I can't even begin to wrap my head around. Tom reminds us that these math problems were "solved" by many professionals over long periods of time, so we shouldn't just expect to understand it immediately (I say "solved" in quotes because there are some values in the problems we don't accurately know yet - the testing done so far has put limits on the values, but they are still technically unknown). Still, after a couple hours of diving into the physics, I'm a bit brain-fried, and yet I desire to go to a classroom where the whole theory is explained to me so I can understand the precise details and wrap my head around the big picture. I imagine this is a good sign - my desire to learn more suggests to me I have, in fact, chosen the right path. I mean, hey, how can you go wrong with physics? :-)

We also drove back into L'Aquila today so that Ali and I could activate our Italian cell phones. They are from Vodafone, so they only work in Europe. We had to get new SIM cards since the ones from last year had expired. I got the right directions from Google maps, but I read them wrong and ended up steering us far off the course. Through a lot of exciting maneuvers and a couple minutes of interesting detours, we finally found our destination - a large indoor shopping mall called L'Aquilone. It took us a lot longer than expected to get everything worked out, since the store (Media World) was very busy with cell phone customers, and it took a while to find someone who could speak some English. It worked out and the cell phones are now operational, but it was yet another experience that reminded me how hard it is to communicate with people when I don't know their language. However, this is a good experience overall because I've realized how much I like the Italian language and want to learn it.

Ok, nighty night! (Or, in your time, good afternoon!)

Robin

## Status Report 4, Sunday, August 9, 2009

By Walt Reil

The Internet is absolutely wonderful. Using Mac to Mac communication, this morning my wife Julie and I had an hour-long video chat with Robin using [Skype](#) at 9:30 AM our time and 6:30 PM in Italy. It was surprisingly excellent. The audio was superb and video was very acceptable, a little choppy at times, but not much. I also recorded our video session using the Skype plug-in application [Call Recorder](#). Now we can view our video phone call at any time. It is incredible having such technology.

Robin was calling from their hotel room. She first gave us a video tour of their hotel room having two twin beds, a clothes closet and a TV.

One interesting thing about using Skype, Robin paid for a service to be able to call land lines in the U.S. from her Skype program. She does not have an international-capable cell phone with her, so Skype serves this purpose of a normal phone in urgent cases.

The Cal Poly team is doing well. Today they spent underground performing another shift reloading liquid helium. The process takes 2 to 3 hours as they meticulously transfer the helium using hoses, valves, etc. They also work with liquid nitrogen. The liquid helium is a key component of the Three Towers neutrino detection equipment, as the system requires super-cold temperatures to permit the detection to occur as desired. When performing the helium recharge process there are certain safety precautions they must take to be sure the supply tank of liquid helium does not become over pressurized by helium turning to gas as they move the liquid helium tank around the room.

When they drive to the underground lab, they drive all of the way through the 6-mile public highway tunnel to the other side of Gran Sasso Mountain where they turn around to drive back into the tunnel to access the lab's entrance tunnel. All of the traffic on the highway drives pretty fast, about 85 mph, including inside the tunnel.

The three of them will be having dinner shortly, probably at the [Hotel Giampy](#) in Assergi a few miles away. Since Tom will be leaving for the U.S. later this coming week, the ladies will have to determine what other restaurants are in the Assergi area, since they will not have the use of Tom's rental car. So, they will be in more of a remote situation that will require traveling by bus when they need to travel some distance.

That is all for this update.

Walt

[Top Of Page](#)

## Status Report 3B, Saturday, August 8, 2009

By Robin Reil

Today we just drove around for a bit, had lunch at the [Hotel Giampy](#) in [Assergi](#), then checked out the small convenience store in [Paganica](#) (just south of Assergi). We happened to run into a woman there named Victoria who is an American from Miami who moved to Italy a couple years ago. She met her Italian husband in Rome at the end of a vacation there, and they emailed a lot, traveled back and forth to each other's countries, and she moved to Italy after about 8-9 months. She gave us some advice about good restaurants to visit, cities to go check out, other B&B's we should check out for future trips, and where to shop for food and other devices. We walked with her just up the street to where her old house was. They don't live there anymore because it suffered too much damage in the earthquake. We met her husband and her mother-in-law who

were both very nice, and we walked around the outside of the house to see some of the damage. We also went into the bottom floor room which was kind of like a separate apartment that they had refurnished with new flooring, appliances, and everything just about a month before the earthquake, but we went in and out really fast since it's not really safe to be inside. We got her email address so that we can ask her more questions and things for if we come again - she was really excited to meet us since she says she never runs into Americans in Assergi, and she really wanted to help us out. I am sad now because I realize I didn't take any pictures of her or her family or her house. I guess I'll just have to come here again and visit her so I can take pictures then. :-)

We also went to [L'Aquila](#) twice (about 12 miles from Assergi). The first time involved a lot of weird side roads and wrong-way stuff because we got a bit lost, but we finally found the large shopping center we were looking for. They had a large supermarket which carried food but also everything you'd find at a Longs Drugs, except I don't think there was a pharmacy inside where you could get prescriptions. Ali and I got a fan to keep our room cool since there is no air conditioning here - just built-in heaters in every room (including the bathrooms) and really thick insulation to keep it warm during the winter months. I also bought what seemed to be sweet jasmine-smelling perfume (it's either perfume or deodorant - either way, it will make me smell good!).

The reason we went back to L'Aquila a second time was because the fan we got turned out to be broken so we couldn't assemble it correctly. It's not too bad to go back to L'Aquila since it's a short drive, so we went back and exchanged it for one with all parts intact (we had them open the other one and take everything out to confirm it wasn't also broken). Of course, when we got back to the hotel we discovered that they had forgotten to put one piece back in the box, but we were able to make do without it, so we now have a working fan to keep our room cool.

Ok, now I'll answer your questions:

#### What kind of hours are you keeping?

Breakfast is served 7:30-9:30 am, so on weekdays we get up around 7:15 to take our showers, have breakfast at 8, and we get to the lab by 9. We usually go to lunch around 1 pm at the lab cafeteria, and after we all go upstairs to the Bar/Cafe where most everyone gets "cafe", which is a shot of espresso, though Ali and I usually get cappuccinos and Tom doesn't get anything. So far, when we go underground we've been taking a shuttle in around 2:30, though that could easily change in the future. We usually get back to the hotel between 4:30 and 5:30, though that could also get pushed back some as our work-loads fill up. Dinner is around 7:30 or 8. Our hotel's restaurant doesn't open for dinner until 8 pm, but the Giampy opens at 7:30. We still need to check out the other restaurants in Fonte Cerreto to find out their hours. Bed time is anywhere between 10 pm and 12 am. Today (Saturday - weekend) we had breakfast around 9 am and then we headed out around noon to check out Assergi, Paganica, and L'Aquila. We might drive up the road to where the Funivia (gondola) normally goes tomorrow or some other time. We will be trying the walk to the lab for the first time tomorrow since we are going underground around 2:30 for another refill.

#### What is the weather like?

It's pretty similar to San Luis Obispo - maybe a smidge cooler. It's generally sunny, though unlike SLO/Atascadero area where the sky usually has a few wispy clouds at all times, here the sky is sometimes completely clear, but more likely it has a substantial amount of really big puffy clouds all around, yet it's still generally sunny. It did sprinkle the tiniest bit the day we arrived, and there have been a few random droplets today when we were out driving. Tom apparently went outside with his computer a couple hours ago and got caught in a little shower that only lasted a couple minutes - Ali and I completely missed it. It also isn't really humid at all; you get a little sweaty during the day if you're outside in the sun, but that's just like being in SLO on a warm day. Our bathroom doesn't have a window, so if you're in there after a warm shower, it's humid in there, but it's fine as soon as you come into the other room. I really like the weather. I'm curious to see how cold it gets during the winter when it snows at least a couple feet.

#### How are your bathroom facilities? Do you have a shower?

Our bathroom looks mostly regular, except there is a built-in heater attached to one wall, and there is a bidet in

addition to a toilet (pronounced twa-let here). Our stand-up shower is particularly small, though I think that is not so common here, as our shower in our first hotel room was the size of a regular stand-up shower you'd find in the USA, as are the showers in the private bathrooms attached to our offices at the above-ground lab (yes, they have showers, an interesting find for us). We are actually considering showering at the lab sometimes because our shower is so small we don't really have room to even wash our hair comfortably, let alone shave our legs. Our toilet functions the same way as in the USA, except the button to flush is usually on the wall above the toilet, and the water tank that normally sits right on top of the toilet is instead mounted on the wall above the toilet, high enough that it's above my head. I also discovered that in some bathrooms there are two buttons to flush - one for going #1 and another for #2 (the difference lies in how much water is used in the flush and how fast it comes out).

#### Does your hotel serve dinner? What is the food like?

Yes, starting at 8 pm. Their particular restaurant does not have physical menus, so you have to ask the waiter about what they serve. Usually he/she suggests something, though you can ask for certain things, like certain kinds of pasta with certain sauces, and they can usually accommodate you. You need to specify it if you're vegetarian, as they tend to not mention that meat comes in sauces or salads. The courses as follows (in order from beginning to end of the meal):

- 1) Antipasto, which can be a variety of things - the other night we ordered something that ended up being a few pieces of bread with different spreads on them, one cheese-based, one meat-based, and one olive-based.
- 2) Primo, which is usually some type of pasta. Common pastas are spaghetti, ravioli, penne, and gnocchi (gnocchi is potato-based, FYI). Common sauces are tomato-based, oil-based, cheese-based, and pesto.
- 3) Secondo, which tends to be some kind of meat and possibly a side of something like potatoes or another vegetable. I have not ordered any of these dishes yet, but I'm sure I will as time goes on and I start getting tired of pasta.
- 4) Insalada, or salad. This can be anything, as we ordered salads on the first night and we each got a large bowl with lettuce, olives, onions, corn, tomatoes (which are delicious here), some kind of bean, and tuna with olive oil to pour on as a dressing, and then today the salad was just a combination of red and green lettuces and tomatoes with oil and vinegar as dressing.
- 5) Dolce or Frutta, so either a dessert of some kind or fruit. We haven't ordered either at dinner yet so far, but at the lab there is usually a large selection of fruit and maybe one or two dessert options at the end of the line. Most everyone at the lab gets a LOT of fruit to eat at the end of lunch.

At the end of a meal, they offer "cafe" - either espresso or any other type of coffee you want to order (cappuccino, cafe latte, etc.). It's very common for people to get this. At the lab everyone goes up to the Cafe after lunch to get their espresso or cappuccino. Usually with dinner we get one or two courses and that is quite enough to fill us up, and we usually get water to drink with the meal. The water is always bottled, and you have to specify which kind you want - "naturale" means without carbonation, and "gassata" means with carbonation. Both kinds are mineral water, though they don't taste any different than regular water. If you want to order wine, you usually just specify the amount ("quarto" = quarter-liter, good for one person; "caraffa" = carafe, good for 2-3 people) and the type ("vino rosso" = red wine; "vino bianco" = white wine). They generally have a house wine which, many times, is a wine they actually make themselves, and it is almost always delicious, and it's also MUCH cheaper than ordering a bottle of something else. I ordered a quarter-liter of red wine last night for 3 euro, and it was about 1.5 glasses - very affordable. You can also order beer ("birra"), which many times comes in very large bottles - probably enough for 2 people or more, though some can drink it all on their own.

#### Do you eat dinner at the lab?

No, since they don't serve dinner there, and since we're not usually there that late, and also, the lab food is fine, but it's quite enough for us to just eat lunch there every day during the work-week. They only serve lunch, and also their cafeteria is not open on weekends. If you need food then you get it from their few vending machines.

#### How different are the foods? Are you able to get salad, soup, bread, etc?

There is variety, though so far I've had a lot of similar things - pasta, more pasta, a salad or 2, bread, one pizza (I'll definitely have more of those, since you can never go wrong with pizza). It's definitely all Italian, meaning as far as I've seen so far, they don't have Chinese food, or Thai, or American, at least they don't advertise restaurants with those foods at all. I could definitely be wrong, though, as I've only been in some small towns and just seen a few glimpses of L'Aquila so far. Salad, soup, and bread are all things you can easily find; in fact, all of those are very common. Bread many times comes with your meal, though some restaurants charge a "cover" that covers the bread cost.

#### How often does the shuttle bus run underground?

It goes about every 10-20 minutes from 8 am to about 7 pm during the week and only every 3 hours between 9 am and 7 pm on the weekends.

#### Are there any offices underground, or is it only the big halls and experiments and you just sit on chairs near the experiment?

As far as I've seen, the experiments are housed in tanks or large shed-like structures, and the control area is either in the room with the experiment or in another small room connected to the experimental housing. Ours is small enough that when we go in we actually go into the room housing the experiment, though there are still MANY layers of shielding and padding between you and the experiment. There are computers on desks, lots of electrical equipment, pressurized tanks of different substances, and lots of random equipment like gloves and funnels and wrenches and O-rings sitting all around. Our room is about 2 stories tall and probably about as big around as a small-medium sized classroom. Directly above the experiment room is a clean room that is used when the tower itself with the crystals and copper framing needs to be handled. There is a small trap door from the clean room down into the ceiling of the experiment room that's used to raise the tower from inside the shielding up into the clean room.

#### Will you be wearing coveralls, or just your normal street clothes with your hard hat?

When underground we need to have on thick pants like jeans, steel-toed shoes, and the hard hats. We usually wear long sleeves like sweatshirts and sweaters as it can be pretty cold in the outer tunnels and the main halls - sometimes cold enough for you to see your own breath - though it's warm enough inside our experimental room to be comfortable in just a t-shirt and jeans. When we go into a clean room, however, (and we expect to at some point during this visit) we will have to put on, as they call it, the "bunny suit" - I don't know much about it yet since I haven't worn one, but it looks like a white suit that goes over your clothes and shoes and head. I think your face is exposed, but it has a hood that cinches tightly around your face to cover your neck and hair.

#### Beside the language, what do you miss from American life?

Bigger showers, definitely. Air-conditioning in the hotel room (though since we bought a fan today that's not as much of a problem anymore). Free tap water at restaurants. Wide roads, wide emergency lanes, sidewalks, and people who pay at least a little attention to speed-limits (the drivers here are surprisingly good at maneuvering through the tiny spaces allowed to them on the roads, but it's still pretty unnerving to watch cars pass each other when there is NO passing lane so that they are just blatantly in the way of oncoming traffic going at the equivalent of ~65 mph). Turning doorknobs (a lot of doors here have what look like an American doorknob, but instead of turning, they just have a button on the top of the knob that you push to open the door). Window screens to keep out big and small bugs alike (we had quite a night the other night when we came back to our room after dinner to discover lots of bugs in our room because we had left our window open).

#### Are any of the lab personnel becoming friends, offering help, showing you things, etc?

Yes, they are pretty friendly. Paolo, Iulian, Luca, and Lucia are the main people I have met there. Paolo and Iulian are kind of in charge of some parts of the experiment, and Luca and Lucia are the current shifters, so

they are training us to do the shifts we'll perform for the next 2.5 weeks. Everyone gives us good advice about all stuff lab-related and some give suggestions of things to do while we're here.

**Is there a secretary you can go to for help with advice and getting any needed office supplies?**

Not that I know of. We haven't really needed office supplies very much so far. We brought our own pencils/pens and notebooks, etc. which is pretty much all we need. I imagine someone there in our project would know where we could get stuff if we need it. There is a library at the top of our main building in the above-ground lab that has some good physics reference books, and if you go to the top floor of it, it's really relaxing to sit and read next to the large windows that look down onto Assergi and the landscape beyond. All of the flooring in there is a warm-colored wood and the whole library is 3 floors which is huge.

**It looks like the above-ground facility is extensive, having a large auditorium. Have you had any time yet to walk about the complex and see what there is? Is there a gift store?**

I have not seen or heard of an auditorium. That might be the library I mentioned above. Though there is a building I have gone into a couple times to meet the woman who gave me access to go underground, and it's possible there's an auditorium in there. I have walked around a little bit, and it's mainly offices. Sometimes there's suddenly a narrow stairway that branches off and upward from the main hallway that leads to one or two more offices upstairs - our office is located at the top of one of those little stairways across from an office that Paolo and Lulian share. As far as I've seen there isn't a gift shop, but I'll have to ask about that. The only thing that could be considered a gift shop is the cafe where people get coffee, but it's mainly used for that - coffee (and sometimes little snacks).

**Do you know yet the walking directions from your hotel to the lab? Is it out in the open and safe?**

We have not yet walked to the lab, but we are going to try in the next couple days. It seems like it should be pretty safe as the little short-cut we plan to take was recently paved, but for some reason it is blocked off to car traffic - it seems there are guys doing some sort of construction or something. We are going to check it out soon, and if it turns out to be a dud we will just take the bus from Fonte Cerreto down to the lab. It's about a 5 minute drive in our rental car, so it would probably take the bus just 10-15 minutes to get there.

**Are you attempting to learn and speak Italian?**

I am definitely trying to familiarize myself with the basics of the language, like the MOST basic phrases and such. I mostly know the numbers 1-10 and a few select others, I know how to say "thank you" (I use that one the most), and I know how to ask for certain types of food. I'm constantly looking up phrases in my phrase book, and I also look up words in my Italian-English dictionary all the time. From time to time I listen to sections of my Italian language CDs, so now I know some words for parts of the house and whatnot. I learned today that "tape" (as in the sticky stuff) is "nastro" when I had to ask to borrow some from the front desk. I know the main salutation phrases, "buon giorno" = "good day"; "buona sera" = "good evening"; and of course "ciao" = "hello" and also "goodbye" (informally). I definitely feel uncomfortable about the fact that I can't communicate effectively with most everyone (some people at the lab are somewhat fluent in English, but most everyone else knows only a few select words to help people like us out). If it seems like a real possibility for us to come back in the winter, I might try taking an Italian language class at Cal Poly this fall to prepare. I do like the language, and I wish I could speak it better.

Robin

Top Of Page

## **Status Report 3A, Saturday, August 8, 2009**

By Robin Reil

Yesterday we went underground and observed a part of the "shifter" duties we will be performing for the next 3

weeks - refilling of the cooling system with [liquid helium](#). It was pretty cool, getting to climb around the equipment and seeing all of the electronics. It was warm enough inside the room housing the experiment that we could take off our sweatshirts and be comfortable.

I followed the expert shifter Luca (a guy) around while Ali followed the rookie shifter Lucia (a girl) around, to observe their tasks, and when we go in again on Sunday to watch it for the second time, Ali and I will switch places to see the whole process. It was a bit crowded yesterday, since shifting is generally a two-person job but we had six people down there - Luca and Lucia, Paolo (he's kind of in charge of us Americans) and Tom, and Ali and I. Next week when we actually start our first shift (this week we're just observing) we will have an expert shifter with us, Luca (different from the Luca for this week - I guess there are about 6-7 guys named Luca who all work on the project; none of them are related) so it will be 3 of us working, though Ali and I are talking about the possibility of switching off so that for each refill only one of us goes down with Luca.

Last night we went to the [Hotel Giampy](#) (where Tom usually stays and where he tried to get us rooms this year) on the outskirts of downtown Assergi for dinner. We each ordered a pizza for 6 euro a piece, and they were HUGE. Thin crust, but at least 15" in diameter. I got [prosciutto](#) (ham), olives, artichokes, and mushrooms on my pizza, and they were separated on the pizza so that each topping sat by itself on one fourth of the pizza. I didn't really like the prosciutto, but the other toppings were really good. I also got their house red wine by myself, so I ordered a "quarto" of it - a quarter-liter - which is about a glass and a half. It was really good, though it was interesting because they served it cold. I will definitely be trying more restaurants' house wines.

We switched rooms to a larger one that has a tiny mini-fridge, a larger closet, and a bigger window. It's definitely nicer, though the shower is a lot smaller. I hit the walls with my elbows when I wash my hair, and I have to open the doors to poke my head out of the shower when I bend over to shave my legs, otherwise I literally have to fold over double to fit in it to shave. I'm going to write an email tonight answering the questions you asked me, Dad, and under the one about missing stuff from the U.S. I will list a large shower. :-)

Well, I need to run because we're going to go out on an excursion to some of the local towns to check out their supermarkets and convenience stores and whatnot. The trip to the Adriatic will have to wait, since we were going to go with Lulian and his fiancée but they aren't free today, and tomorrow we're going to observe another cooling system refill.

Robin

[Top Of Page](#)

## Status Report 2, Thursday, August 6, 2009

By Robin Reil

Today was pretty good. Our continental breakfast is nice; lots of puffy pastries and yogurt and cereal (which you evidently put in the yogurt as there is no milk provided) and interesting juices. We went to the lab in the morning and got ourselves situated in our offices - we have two since we still have the old one that was given to us (us being the groups from America - we are the only ones currently here from the US) and we also got a new office that was temporarily used as a living space for one of the CUORE project people after his family's house was damaged in the earthquake. Then we had lunch and then "cafe" (coffee - mostly espresso shots and cappuccinos) and then we went underground.

The ride is about a ten minute drive through the underground tunnel, and then you immediately turn around and go back through the tunnel in the other direction, and then there is a little side lane that takes you up to the lab entrance. There is a big metal door that opens for the shuttle van to drive through and then you're let out to swipe your badge at the guard's shack. I just have an email print-out that I give to them along with my



passport, and they keep them both in exchange for my visitor badge, whereas Ali and Tom have their own badges with their pictures and everything since they took the safety training before. I can't take the training until about 3 days before we leave for Switzerland since they don't offer it in English until then.

Underground is cool. In the outer tunnels, which are big enough for a small semi-truck to drive through, it's cold enough for you to see your breath, but inside the main tunnel and the 3 big halls that branch off from it are a bit warmer because of all the electronics from the different experiments. There is a lot to see there, and you are actually pretty free to roam around other experiments, but we stayed clear from a lot of stuff since Tom doesn't know much about the other experiments and so we could easily put ourselves or others in danger if we're not careful.



I got to see the platform that is still currently under construction that will house the big CUORE experiment - a large solid concrete slab sitting on top of these huge metal bolts that allow the slab to be raised or lowered, and the whole thing is on big shocks to keep things stable. The experiment itself is not there yet, though, because it will still be in development for a couple more years. I also saw the smaller room that houses the Three Towers project we'll be working on, but we didn't go in to see it since we didn't know if they were currently running anything and we didn't want to possibly wreck data and whatnot.

After that we came back to the above-ground lab for about an hour, where we just hung out, and then we went back to our hotel. Ali and I walked for a few minutes to get down to the "downtown" area of Fonte Cerreto - pretty much just 5-6 hotels with attached ristoranti and cafes/bars (I guess "bar" and "cafe" are essentially synonymous here), a hot-dog stand, and some little huts that are open in the middle of the day to sell random trinkets. Ali got an ice cream bar at a cafe and I bought a large magazine for 2 euro. We also walked up to the Funivia, where the gondolas ([photo 1](#), [photo 2 not by the Cal Poly team](#)) go from Fonte Cerreto up the mountain. We saw signs that seemed contradictory - one seemed to say "Closed for Maintenance" and the other gave hours of operation listing "Morning" and "09:00" and "13:00" Monday-Friday. We later asked the girl at our hotel if it was open and she said "No" and a whole bunch of stuff in Italian. So we're thinking of getting Gutierrez to take us up to the observatory in the car since the Funivia would normally take us up there. We're also thinking that on Saturday or Sunday we'll drive over to the Adriatic Sea and look around and possibly

swim.

Tomorrow we're going to get more into the training by observing some of the underground work that we will be doing when performing our shifts. That's as much as we know for now. I attached a small version of a picture Tom took of me and Ali in the underground tunnel between the guard shack and the entrance to the main tunnel.

Robin

Top Of Page

## Status Report 1, Wednesday, August 5, 2009

By Walt Reil

Tom, Robin and Ali landed in Rome at 8:30 AM this morning (11:30 PM Pacific Time last night) following 18 hours of flights from SLO to San Francisco to Washington D.C. to Rome.

Robin is extremely excited to have the opportunity of being part of this research adventure, her first time traveling outside of the U.S. She is experiencing a crash course in Italian, studying language CDs on the flights, and now fully immersed in it, face-to-face, in Italy. I think she enjoys learning languages on the fly. She states that the couple-hour drive from Rome to Assergi was beautiful, looking a lot like California.

Upon arrival in the village of [Assergi](#), population 500, they visited the lab's above-ground office facilities ([photo not by the Cal Poly team](#)), had lunch in the cafeteria with CUORE project personnel and are preparing to obtain unescorted security access to the underground lab tomorrow.

Then they checked into their mountain ski-resort [Hotel Nido dell' Aquila](#) (website is in Italian, but it has some good photos). As described by another website "The style of a mountain chalet. The hospitality of a charming hotel. Completely surrounded by the breath-taking beauty of the Gran Sasso National Park, suited for those who love sport, nature, traditions."

As Robin eagerly reported in her first report this morning, the hotel is very cozy, having numerous pretty sitting rooms and patios and wireless Internet. And it has a beautiful dining room and a great outdoor swimming pool with a commanding view of the mountainous country. She immediately pulled out her laptop (belonging to the research project) and started her communications with us. We plan to start video chats shortly.

She just can't believe she is in Italy and involved in such fascinating research, like a kid in a candy store. Ali participated in this research program at LNGS last summer, so she has a foundation of some experience in the area and traveling around Italy. Robin and Ali are part of a larger team of college students from other universities who are taking turns working shifts at the lab to support various research projects. Their first week will be devoted to in-depth tours of lab operations and technical and safety training to learn how to operate and support the project's operations. Then they will spend most every day tending to the experiment, wearing steel-toed boots and protective lab equipment. Each day they pass through access facilities having armed guards who check their IDs.

On weekends they will venture to Rome and hopefully Venice, Florence and other cities by train to see the beautiful sights. They may also get an opportunity to visit a local astronomical observatory located nearby, Rome Observatory's Campo Imperatore site ([photo not by the Cal Poly team](#)) on Gran Sasso Mountain.

At the conclusion of their month's tour of duty at the lab, they will fly to Geneva, Switzerland ([photo not by the Cal Poly team](#)) for several days to visit CERN's [Large Hadron Collider \(LHC\)](#), the world's largest underground particle accelerator, located 300 feet beneath the France-Switzerland border, which should start

operations this October.

That's all for this first report.

Walt

Top Of Page

Header image of galaxy NGC 891 by **Johannes Schedler** at [Panther Observatory](#), Austria

[Home](#)

[Technical](#)

[Status Reports](#)

[Photo Gallery](#)

