



Public outreach at the Soudan Underground Laboratory

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Abstract

There are many facets to the outreach program at the Soudan Underground Laboratory, currently host to the MINOS neutrino oscillation experiment and the Cryogenic Dark Matter experiment, plus a number of smaller experiments in the Low Background Counting Facility. The main focus is on twice daily public tours, operated in coordination with the Soudan Underground State Park and Minnesota Department of Natural Resources, who also operate underground tours of the historical iron mining area. Another important component is the undergraduate interns and high school teachers who lead the tours. They also participate in the operation and/or analysis of the experiments hosted at the mine.

Keywords:

1. Introduction and history

The Soudan Underground Laboratory has been the location for physics experiments since the Soudan-1 nucleon decay and neutrino experiment. Outreach activities began 35 years ago with a town hall meeting in fall 1979 during the installation of that experiment. Today, the expanded laboratory is the site of the MINOS neutrino oscillation experiment [1] and the cryogenic dark matter survey (CDMS) for their CDMS II phase [2] and the current SuperCDMS phase [3], the multi-user Low Background Counting Facility built in the refurbished muon veto shield of the Soudan2 experiment [4], with the newly operational NOvA neutrino oscillation experiment [5] just 125 km drive away. The laboratory and the underground mine that hosts it are in a Minnesota State Park which provides unique opportunities for education and public outreach programming.

Today the lab's outreach program is centered on twice daily public tours during the summer and into the autumn. The state park, operated by the Minnesota Department of Natural Resources, is based around underground tours of the historical mining area that was actively worked just prior to the shutdown of mining operations in 1962. The laboratory itself is operated by the

University of Minnesota. Early outreach activities were supported through the University and researchers on the experiment, and included an open house day.

Around the year 2000, a summer program led by interns began to be supported primarily through the University of Minnesota and through the United States National Science Foundation (NSF) grants to universities involved in the MINOS experiment. Recently the outreach program's main support has been formally consolidated into a single NSF grant, though opportunities and partnerships that provide other forms of support are important and enhance the activities at the lab.

2. Outreach program today

The program is both stable and changing. The basic structure of the program has been similar for the past ten years, but there are new opportunities and challenges every year.

Public tours, interns, and high school teachers

The laboratory and state park operate a summer tour season. It is in a region known for boating and fishing, and is on the roads to enter of the Boundary Waters Canoe Area Wilderness. Because of this, the park enjoys

substantial tourism traffic during the summer. The historical mine tour is the primary advertised draw to the park. The lab tour is also advertised and is a clearly available option when people are there. The underground mine tour is offered throughout the day, while the laboratory tour is available twice or sometimes three times a day.

The current program involves support for three undergraduate interns and two high school teachers during the summer season, plus an outreach coordinator who works half-time all year round. This is enough to fully staff the twice daily tours at Soudan, plus allows for two people to spend a day at the NOvA far detector site. At Soudan, the tour typically has stops to describe neutrino oscillation physics, the MINOS detector, dark matter physics, and the CDMS detector.

The interns are recruited through advertisements at a few regional colleges and universities, plus the actual position announcement at the University of Minnesota Duluth Human Resources website. The program gets as many applicants who knew about the program from their own past experience. Such students are usually from Minnesota and had an opportunity to learn about the mine as a tourist or through a high school teacher who arranged a tour for their class. The high school teachers are recruited from northern Minnesota region, and we make an effort to recruit new teachers to join an experienced teacher at the mine.

Though the tours are the primary outreach product, the summer group has time during the day for other activities. Typically they have a mix of backgrounds and interests: physics, other science, engineering, education, even history and journalism. One natural activity to add to or improve the posters and demonstrations used, based on feedback they get as they tell the story on the tour and listen to questions asked by the public.

Open house and community activities

Another important outreach opportunity is the day long laboratory open house hosted in May. Unlike the summer program which draws from the tourists visiting the region, this one is attended primarily by people who live in the region, the laboratory's neighbors. These tours are offered for free, and typically are led by physicists who were already on site doing shifts for the experiment or traveled to the site just for the day.

Also for the community, many K-12 and undergraduate college groups come and take tours, about 1/3 of the laboratory's annual traffic. Their program is similar to the standard tour we offer with an optional extended program. One of the duties of the outreach coordinator

is to go out to the community and give talks and lectures. These also include K-12, undergraduate, and senior lifetime-learning educational groups, but also community groups such as service clubs, library events, and regional science and engineering fairs.

3. Physics projects for summer interns

Another activity is to participate in the maintenance, operation, or analysis of the experiments installed in the lab. Our interns have typically finished their first or second year in college, so they are still a year early to be accepted into a typical Research Experience for Undergraduates (REU) program at universities in the United States. Some projects, like testing and refurbishing spare equipment and performing daily detector operation checklists are suitable for students without much prior experience.

More advanced projects are possible with the right combination of intern and involvement from researchers. Neutrino experiment analysis often involves using an event display and eye-scanning for some feature of the signal or background in support of developing or validating a reconstruction algorithm. Visual, topological features of these events are conceptually very accessible to people who are not yet experienced in the detailed physics. Indeed historically an important contribution from the technical (not outreach) crew on the Soudan2 experiment [4] was to visually scan all the data and MC selected as neutrino or proton decay candidates.

The technical aspect of organizing a visual scan of some events for some feature is helped enormously by web browser based event visualization. The event display built for MINERvA [6] is so full featured that it is the only event display the experiment uses for all needs. It uses a HTML5 standard and AJAX technology where the client pulls data from the server through a well-formed URL, but all drawing and manipulation of the visualization is done on the client computer without needing any browser plugin extensions. It is so successful that a version has been made for the MINOS experiment. People doing the event scanning are able to work from a simple list of html links on any convenient computer, and only need to learn the topology and data entry aspects of the analysis.

This kind of task is one of the most physics rich and the closest to physics analysis, though it requires that physicists have a question that is best answered this way and have the time to devote to working with the interns. Having an event display accessible with a web browser allows for purely educational activities suitable

to bring in for a high school class. One such example is the MINERvA Neutrino Classroom [7], which was put together with substantial contributions from two high school teachers who spent their summer at the Soudan Underground Laboratory.

4. Future

Particle physics and their infrastructure arrives and leaves slowly, so there are always steady changes and new opportunities that affect the outreach programming at the Soudan Underground Lab. New experiments appear and become a part of the tour while older experiments are phased out of the narrative.

NOvA experiment

At this time, the NOvA experiment [5] has just finished construction and has begun full operations. The NOvA far detector laboratory is a compelling place for a tour and does not require the personnel infrastructure needed for an underground visit. This allows for more fluid timing and allows the tour leader to mix more informal conversation with a set tour talking points. On the other hand, the NOvA far site does not benefit directly from being in the same location as a known destination as the Soudan Underground Mine historical tours provide.

Lake Vermilion State Park

Another slow change is the presence of Minnesota's newest state park, the Lake Vermilion State Park, which will share a border with the Soudan Underground State Park. Unlike the former, which is focused on the history of iron mining, the new park will explicitly have camping, boating, and other typical outdoor activities. Bringing a new state park into operation and advertising it is a methodical process, but the proximity means we expect it will bring a larger number of people interested in the historical and science aspects of the lab.

Sanford Lab and Fermilab

In addition to the outreach activities directly funded, the program has several kinds of interactions with other education and outreach groups.

The past three years, the undergraduate interns have taken a road trip to Fermilab. The modest travel expense has been supported by the University of Minnesota Twin Cities. They have done this in the gap between the end of their weeks at the lab and the beginning of classes at their undergraduate institution. They already have had the full summer experience, so this trip can be busy and

full without being overwhelming. Some of their tour is provided by the Fermilab outreach team, some of it has been provided by the experimenters themselves, both graduate students, postdocs, and faculty and scientific staff. It gives these undergraduates an expansive view of what it takes to bring together major experiments like these, and how they might play a role at all stages, as students, engineers, and physicists. It's been a great capstone to their experience.

Some of the groups who come and tour the lab are there by special arrangement. For two summers, a group from the Sanford Lab summer science program has taken a tour that included visits to the NOvA and Soudan laboratories. Excursions to the Soudan Lab are often offered when physics conferences are hosted in Minneapolis. Such was done for the 2013 "Snowmass" conference and the 2014 summer American Association of Physics Teachers conference. Regular interactions such as these maintain our contacts, seed potential new partnerships for our program, and in some cases provide applicants to serve as summer interns.

5. Conclusion

There has been 35 years of outreach activities at the Soudan Underground Lab. Recent support has allowed for a program that is both stable and ever changing. The program has served over 40,000 visitors in the past decade from many different constituencies, including regional and national tourists, scientists and science educators, educational groups from the region, and members of the community that are the lab's neighbors.

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