SNOLAB Particle symphony

INTRODUCTION

SNOLAB is an underground science laboratory. It's located 2 km underground deep inside the active Vale Creighton nickel mine in Sudbury, Ontario. SNOLAB hosts sensitive experiments to help scientists detect invisible particles like neutrinos and dark matter. Here on the surface of the Earth, there is cosmic radiation from space that would interact with the experiments and prevent scientists from being able to detect the signals they're looking for – it would be like trying to listen for a pin drop at a concert! By hosting the experiments 2 km underground, we can reduce the radiation by a factor of about 50 million!

In this activity, participants will journey from the Earth's surface 2 km underground into SNOLAB and inside a detector. Along the way, participants will learn about the ways that the detectors are shielded from different types of background radiation.

LOGISTICS

Activity	Group size	Time	Materials
Journey to SNOLAB	Whole group	30 minutes	• Slide deck • Instrument or sound for each particle – 6 total • Plastic containers full of rice, marbles, a ping pong ball, drums, tambourine, etc. NOTE: You could also use different body sounds such as clapping if instruments are not available. Just make a visual for each of the 5 sounds that will represent each of the particles.

CONNECTIONS TO SNOLAB SCIENCE

This activity gives insight as to why astroparticle physics research about outer space are sometimes conducted underground. This activity highlights the types of shielding used to protect these very sensitive detectors from background radiation, so that scientists may observe the signal they are looking for.

PROCEDURE

Journey to SNOLAB

There are a lot of particles that need to be kept out of the very sensitive experiments at SNOLAB in order to detect neutrinos and/or dark matter. An instrument or sound will be assigned to the different particles (sources of background radiation), that need to be reduced to make neutrino and dark matter searches possible in the experiments at SNOLAB. All instruments (sounds of particles) will be played together in the beginning (at the Earth's surface) and as we travel to SNOLAB and inside a detector, they will each be eliminated, leaving only the sound represented by the neutrino or dark matter at the end of the activity.

To do in advance:
Assign an instrument or sound to each of the 5 “background noise” particles. We used a toy drum, tambourine, clapper, rice in a plastic container, and a ping pong ball in a plastic container. Alternatively, you can use sounds like clapping hands, snapping fingers, stomping feet, rubbing paper together, humming, clucking tongue, animal noises – whatever you like! In order from loudest to quietest instrument, we ordered them muons, neutrons, gammas, betas, alphas.

Slide #	Instructions/storyline
1-5	Begin the slideshow to introduce SNOLAB and the research we do (slides 1-5). Scientists at SNOLAB study space from deep underground. Brainstorm: Can you think of anything that you know is there but cannot see? E.g. wind, air/pressure, gravity, electricity, UV light, microwaves, sound. How can we detect and/or measure these things?
6-8	Explain why a science lab would be located 2km underground. The 2km of rock is very good at blocking out cosmic rays, creating a low background environment, so that our sensitive experiments can see the other rarely interacting particles they are actually studying. This search for rarely interacting particles can be like trying to find a pin drop in a crowded dance floor. To actually hear the pin drop you would need to get rid of all the background noise!
9-10	The cosmic rays that we block out are from a variety of sources, including supernovae and our own sun. A way we can see cosmic rays with our eyes is the Aurora Borealis/Northern Lights! This phenomenon is created by cosmic ray particles interacting in our atmosphere, with the different colours representing the different gases.
11-14	Pass out instruments and ensure participants know which particles their instruments represent. We kept an extra copy of each instrument to hold up to demonstrate which instruments should be playing. While participants are playing their instruments, quietly snap your fingers or make another very quiet sound to represent the neutrino. We usually do not point it out until the very end once it is silent. The soundscape can be done without instruments by assigning a sound to each different particle. For example, a clap could be a muon. You just need to make a visual cue for each sound!
15-18	We start our journey to SNOLAB on the Earth’s surface. Here, we experience all of the natural background radiation – this means we hear *all* of the instruments! Allow participants to play all of their instruments/noises.
19	Watch the video to preview the journey to SNOLAB and inside of a detector.
20-25	Next, we get in the cage and descend 2 km underground to the lab. The 2 km of rock overburden reduces muon flux (cosmic ray) by a factor of about 50 million! Muons are heavy, high energy, short-lived particles. Most are created by collisions of high energy cosmic rays with particles in the atmosphere. When we arrive at the lab, students play their instruments again – this time without the muons.
26-31	Now that we’re underground at the lab, we need to rinse off any mine dust in the shower and clean any of the equipment we bring with us. The rock and dust in the mine (naturally high in uranium and thorium) are a huge source of neutrons. Once we’re dressed in clean room clothing, we’re ready to take a look inside a detector. Many of the detectors are housed inside a water tank. The water serves to slow down neutrons and reduce their energy. Once we’re inside the water shielding, have participants play their instruments again – without the neutrons or the muons.
32-37	The walls of the lab and materials the experiments are built with can be a big source of gammas. Gammas are given off during the decay of radioactive elements. They are reduced by using shielding materials like lead and copper (with heavy nuclei) around experiments.

	Once we're inside the copper or lead shielding, have participants play their instruments again – this time without the gammas, neutrons, or muons. It's starting to get pretty quiet!
38-42	Betas are high-energy, high-speed electrons or positrons emitted by the decay of radioactive elements. They are present in materials and are reduced by selecting ultra-clean materials with no radioactive elements. Betas only travel about a metre in air, so if they are present, they come from the materials the experiment is made from. Once inside the detector made with ultra clean materials, have participants play their instruments again – this time without the betas, gammas, neutrons, or muons.
43-48	Alphas are large, slow, positively charged particles made up of two protons and two neutrons. They are present in materials and reduced by selecting ultra-clean materials with no radioactive elements. Alphas only travel a few centimetres in air so if present, they are from the materials in the experiment. Now that we're inside the experiment made with ultra clean materials, it should be quiet enough to hear a neutrino or a dark matter particle – no muons, neutrons, gammas, betas, or alphas!
49-51	Reveal that the neutrino was there all along, but we just couldn't hear it with all of the other noise present!

DEBRIEF & REFLECTION

Can you think of things that you know exist but you cannot see?

How can scientists look for something that they cannot see?

REFERENCES

[How to build a dark matter detector – short animated video.]

CONNECTIONS TO ONTARIO CURRICULUM

Ontario curriculum connections should be organized by grade level, subject area, strand, and list the overall and/or specific expectation the activity addresses in bullet points.

Grade 9 Science, Chemistry

- Overall expectation C3: *"demonstrate an understanding of the properties of common elements and compounds, and of the organization of elements in the periodic table."*