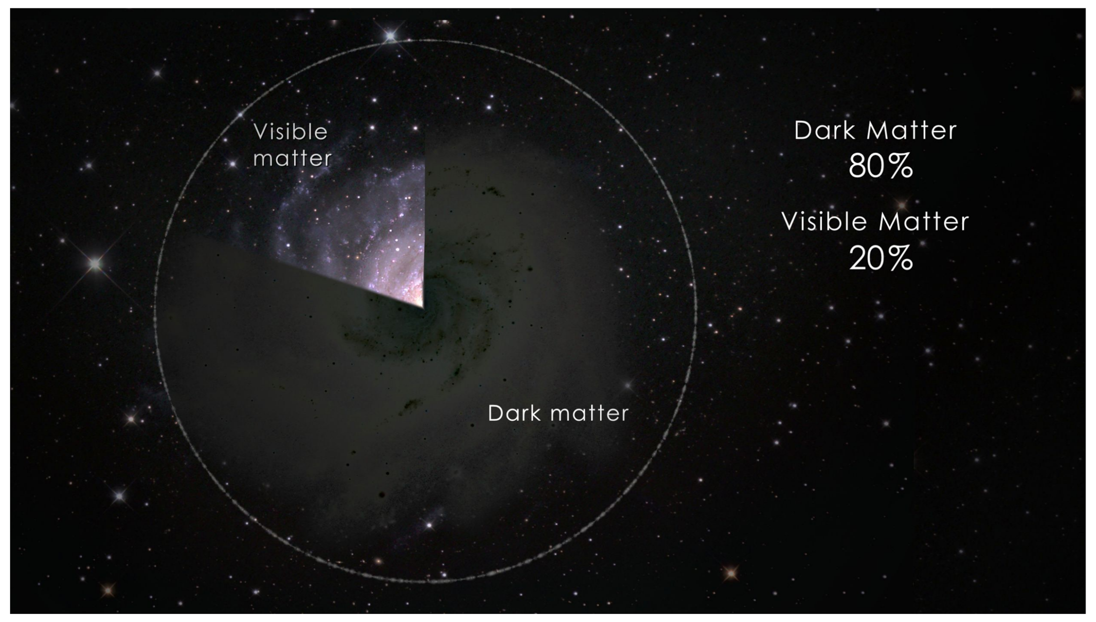
Unearthing the Secrets of the Universe: Simulating Neutron Calibrations for the MiniCLEAN Dark Matter Detector

N. Eggen, K. Palladino

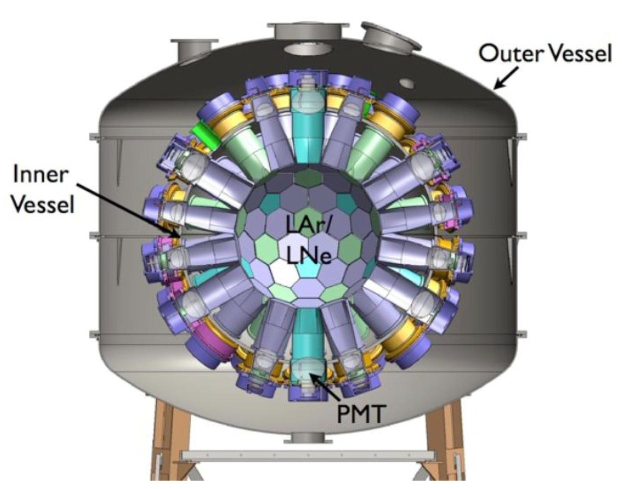
Abstract: Using RAT, a Geant4-based Monte Carlo analysis tool, I have run neutron calibration simulations to estimate the time calibrations will require for the experiment MiniCLEAN. MiniCLEAN is a direct dark matter detection experiment that will begin taking data this spring. It is located 6800 feet underground at SNOLAB in Sudbury, Ontario Canada. The experiment uses liquid argon as its detection medium, searching for Weakly Interacting Dark Matter (WIMPs). The neutron source Americium Beryllium (AmBe) generates neutrons that will scatter off of argon nuclei in the detector to calibrate what a dark matter collision would look like. A framework for data processing, ROOT, was then used to interpret the simulated data set and the source was found to generate 7 to 8 events per minute



What is Dark Matter?

Dark matter is an unidentified form of matter different from normal matter. Like the normal matter that makes up everything we see, it interacts with other matter through gravity and the weak force but unlike normal matter it does not interact with light and so we cannot see it directly when observing the universe.

Based on its gravitational effects on the matter we can observe it is estimated that about 80% of the matter in the universe is this mysterious dark matter with the remaining 20% being visible matter.



The MiniCLEAN Detector

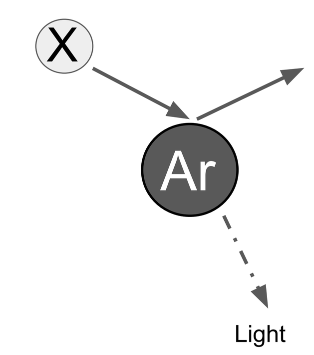
MiniCLEAN is a first generation dark matter detector located at SNOLAB in Sudbury, Ontario Canada. SNOLAB hosts many experiments ranging in fields from neutrino physics to biology to dark matter physics and is located underground in an operating mine, 6800 feet below ground. MiniCLEAN utilizes 2000 kg of liquid argon to detect WIMPs. Argon is being used due to its scintillation property and its relatively cheap cost as compared with other alternatives like Neon. Scintillation is a process where light is emitted by the medium, in this case argon, in response to the interaction of it with a passing particle.

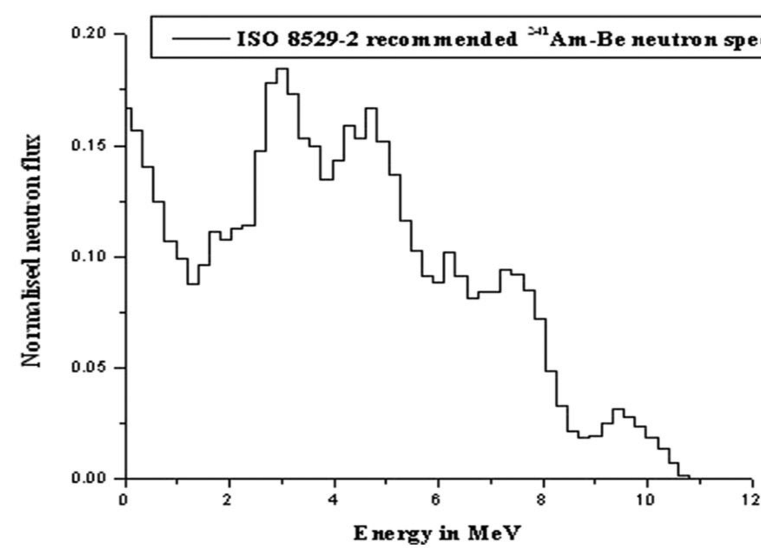
MiniCLEAN is different than other dark matter detectors in that the light detectors (PMTs) which detect this scintillation light are directly in the liquid argon rather than embedded in the walls of the tank that contains the liquid argon.

Last year miniCLEAN was slowly cooling down toward the temperature argon starts condensing into liquid. In order to speed up this cooling process, I was fortunate enough to be able to travel to Sudbury and help set up a condenser (as seen in figure x), which was designed to cool the argon and condense it before flowing into the detector. Specifically I formed and cleaned the piping that connected the purification system to the condenser and then the condenser to the detector. The condenser went into operation in late august last year and Figure x shows the effects on the cooling of the condenser.

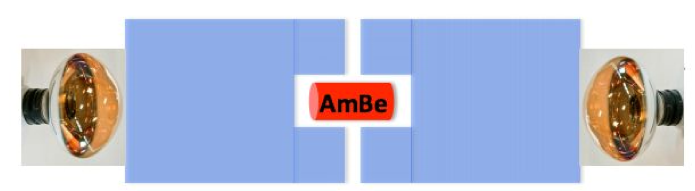
Neutron Calibrations

Scientific Motivation: When a WIMP scatters off of argon nuclei, it imparts some of its energy and excites the argon which then emits scintillation light. In a single phase detector like miniCLEAN it is crucial to be able to differentiate between electronic recoils and neutron recoils and the typical way to do this is to look at the fraction of light that gets detected in the first 90 nanoseconds which we denote "fprompt". In order to calibrate what these nuclear recoils look like we utilize neutrons, whose interaction with the argon look very similar to a WIMPs interaction. However because of the sensitive experiments going on in SNOLAB, we must understand how long the neutron source will be needed.

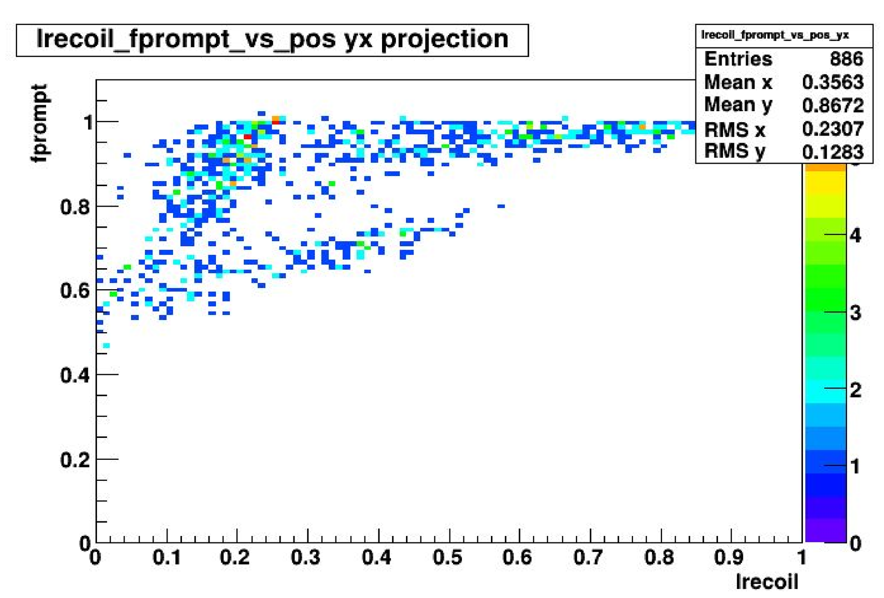


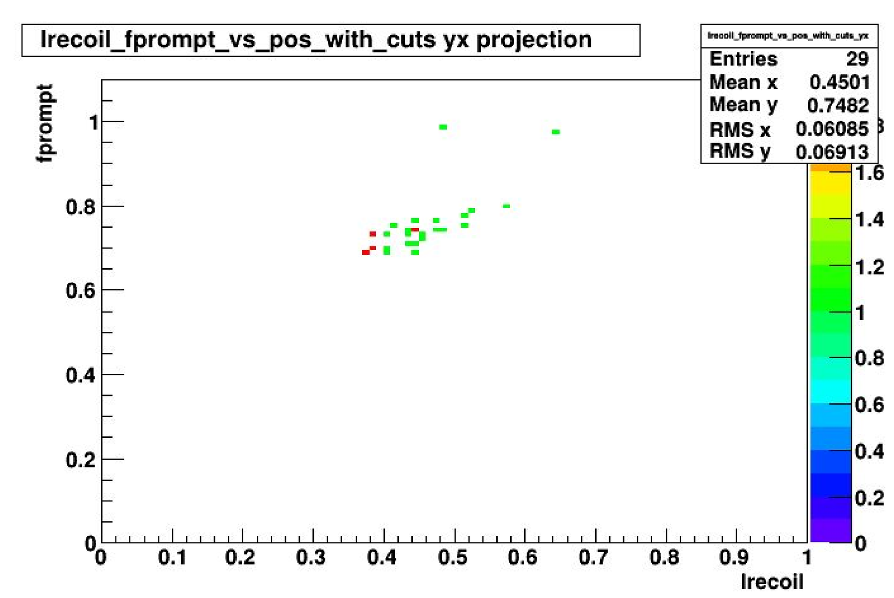


The AmBe Source: The neutron source miniCLEAN will be using for its calibrations is the americium beryllium (AmBe) source. The source emits about 5000 neutrons per second and has the energy spectrum in figure x.



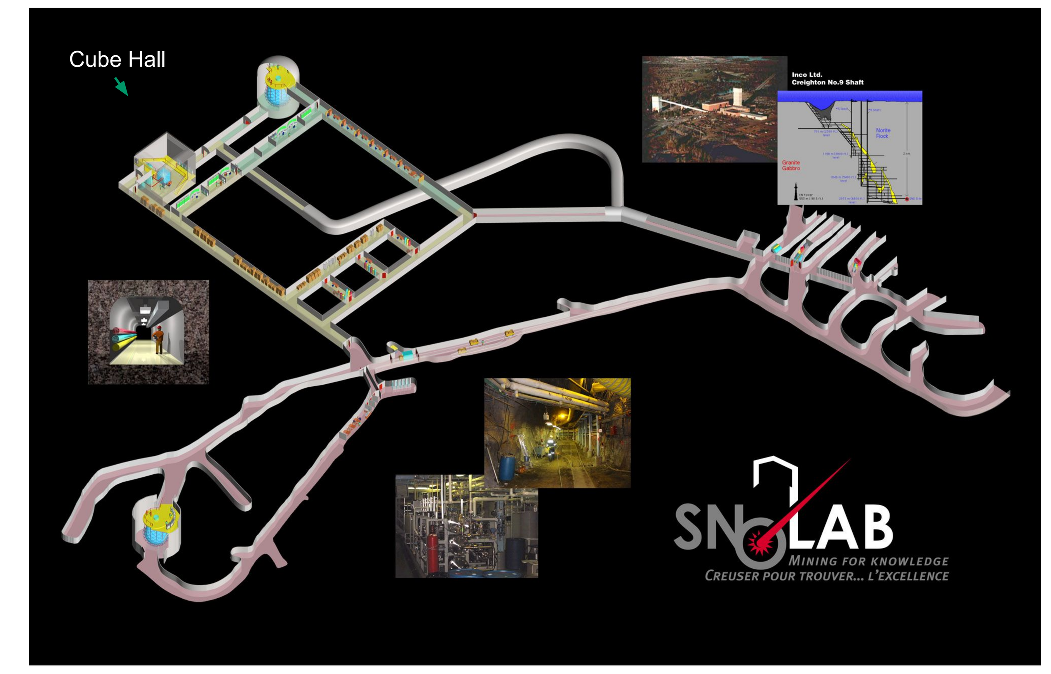
(Insert picture of source or nuclear decay chain?)





(Above) Figures showing the effects of the various cuts used and how different events in the detector are differentiated.
(Below) Final tally of the number of events triggering a response from the pmts, passing the various cuts, and the number of clean nuclear recoils. Based on the AmBe emission rate, a timeline was developed for the actual neutron calibrations.

Number of Simulated Events	Number of Triggered Events	Pass PE Cuts	Pass Lrecoil Cuts	Pass Radial Cuts	Pass Fprompt Cuts	Pass All Cuts
200000	3186	838	360	1756	772	28



The future of MiniCLEAN

	Task	Complete
Installation	Inner Vessel Completed and Tested	✓
	Inner Vessel Installed in Outer Vessel	✓
	Support Hardware Installations (Vent Pipe…) Completed	✓
	Purification System Completed	✓
Commissioning	Detector Cooled (87 K)	✓
	Detector Filled	In progress
	Physics	Mid 2016