Utilization of Neutrinos to Monitor Nuclear Proliferation

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Motivation

Nuclear weapons are the most destructive weapon ever created by man (Semkow et al., 2007). The IAEA is tasked with keeping track of the use of nuclear material and making sure that nuclear power plants are only being used for power and not a cover to harvest needed material to create a nuclear bomb. In a nuclear power plant, when the 235U (Uranium) undergoes fission its nucleus splits and as the material continues to split it changes from uranium to Pu (plutonium) and at one point the core will have a high percentage of 239Pu. This is important because the isotope used to make a nuclear bomb is 239Pu. All that is needed is to chemically extract the 239Pu and replace the core into the reactor to hide their actions (Safeguards and Verification | IAEA, 2020). The IAEA could detect states committing this act if they could access these facilities and frequently check the plants and the reactors core. Sadly, this is not the case in many places, where the IAEA must wait until the government dispatches someone to escort them around the plant (Safeguards and Verification | IAEA, 2020). To overcome this obstacle there is an idea proposed, called The Watchman Project; it use the neutrinos that come from the beta decay of radiative matter, to track its use and location (Askins et al., 2015).

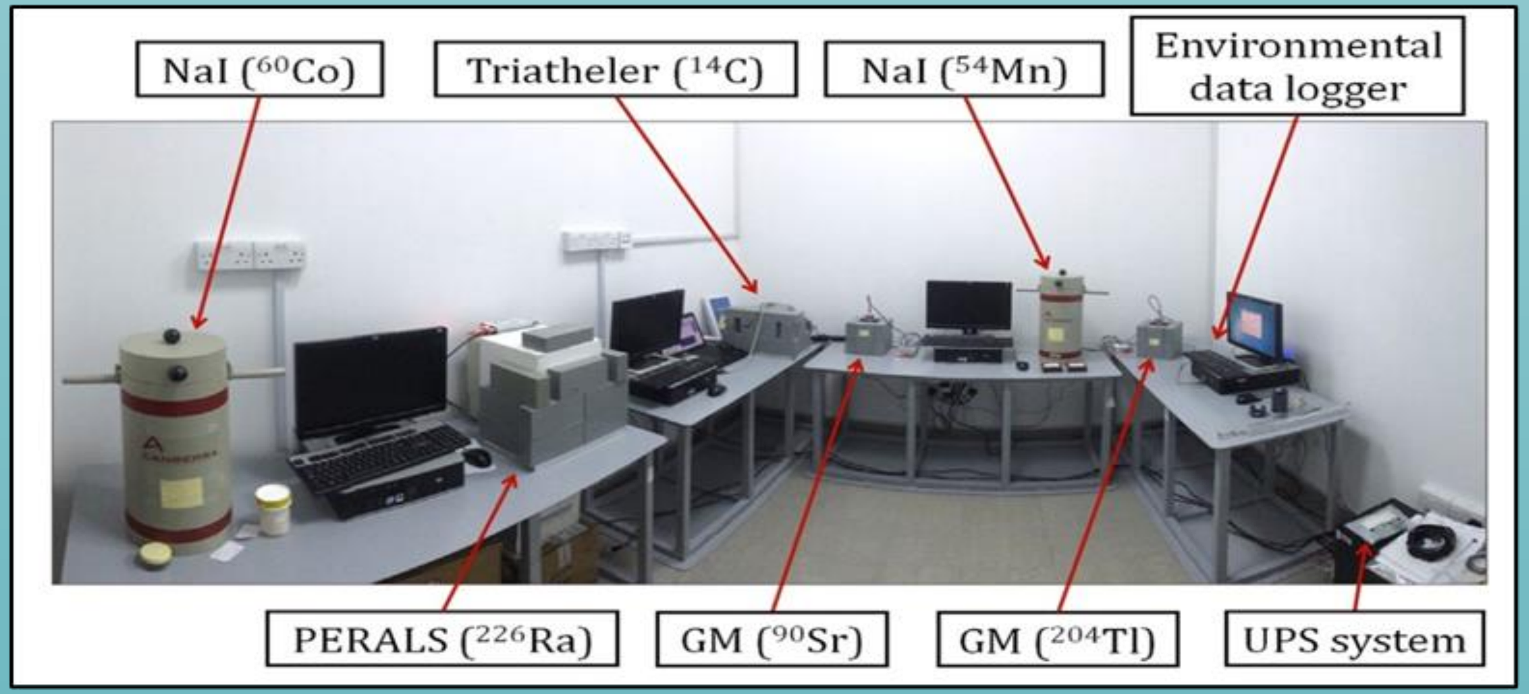
Background

Neutrinos are subatomic particles that rarely react with matter. They are created when radioactive matter goes through beta decay, which happens through fission reactions, fusion reactions, or naturally to some isotopes (Kim & Pevsner, 1993). As beta decay occurs the atoms a neutron will become positively charged turning it into a proton (Kim & Pevsner, 1993). This causes a need for a negative charge to counter act the positive one, to do this an electron is created; for an electron to be created from nothing an anti-electron component must be created to cancel out its addition to the universe, this anti-electron component is a neutrino (Kim & Pevsner, 1993). Since neutrinos do not react with much matter, they are very hard to detect; during this experiment, an inorganic scintillator was used to detect these subatomic particles.

Scintillators were first used in 1896 by Becquerel, when he used CaWO4 (Calcium tungstate) to show radioactivity of uranyl salts (Weber, 2002). The inorganic scintillators work by absorbing the energy from neutrinos, which gives an electron enough energy to jump from the valance band to the conduction band. When this happens, a photomultiplier tube absorbs the burst of light and records it (Weber, 2002).

Methods

- A MadgeTech PRHTemp101A data logger was placed in the room, at least 10 cm away from equipment that had the potential to generate heat, to record the humidity, temperature, and pressure in the room (Goddard et al., 2016).
- A Canberra NAIS 2×2 – NaI(Tl) LED temperature stabilized scintillation detector connected to a Canberra Osprey multi-channel analyzer (MCA)(Goddard et al., 2016).
- The radioactive material used during the experiment is 2.5570.51 µCi of 60Co (1/1/2015).
- The detector was shielded from external radiation sources by using 4π graded Canberra model 727 lead shield (Goddard et al., 2016).



Results

From the experiment it is evident that the change in environmental factors were statistically sufficient to conclude that the environmental factors effect the number of neutrinos released from the decaying isotope as seen in figure 2. While the trendline of the neutrino count is constantly decreasing the spikes in the neutrino count show a correlation with the spikes in temperature.

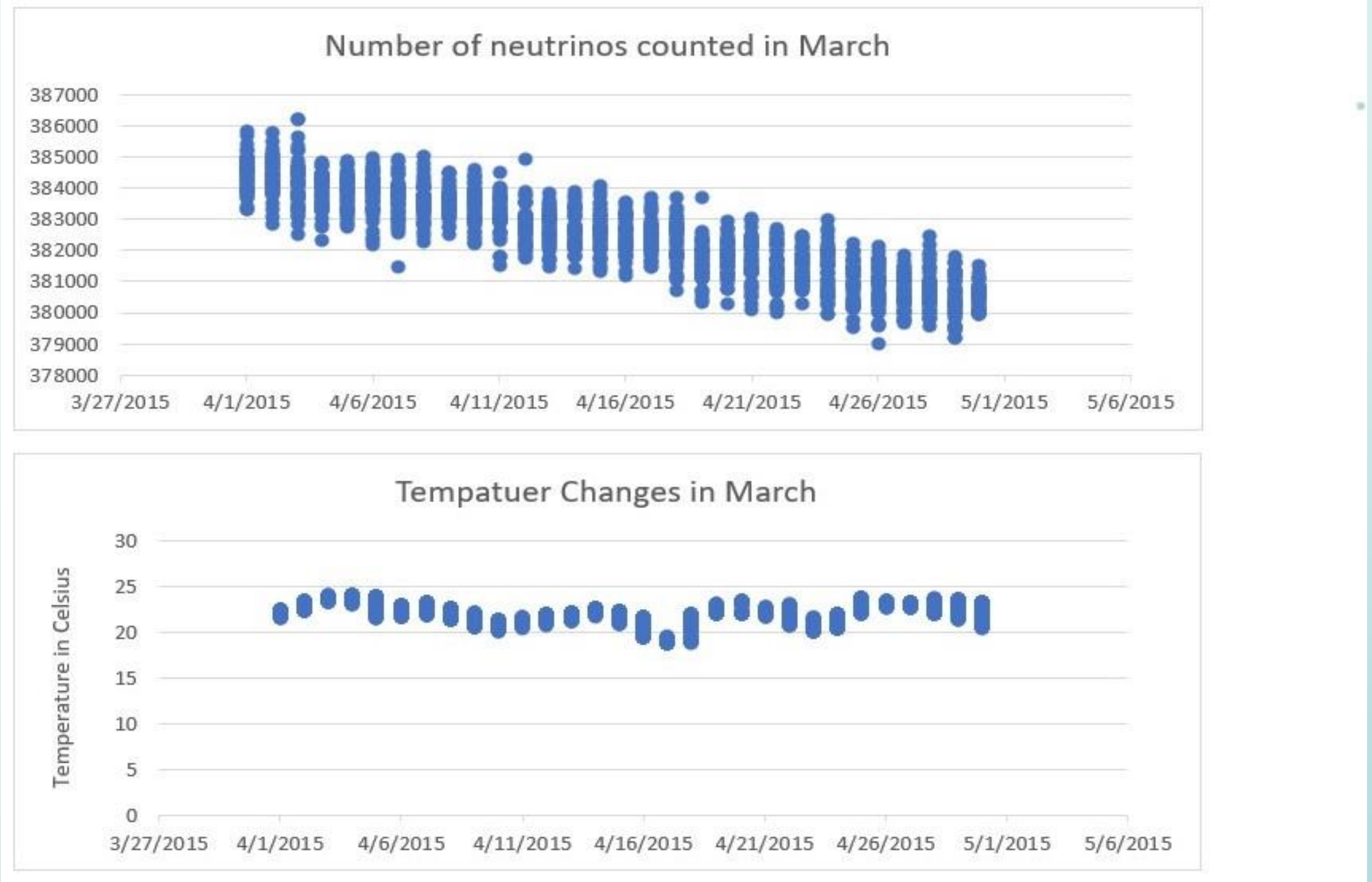


Figure 2: This is the data collected from the March 2015, showing the neutrino count as well as the temperature changes.

These findings are support similar findings from the Khalifa University of Science when they tested a similar isotope (magnesium) in the same setup. In figure 3 it shows that as the temperature increases and decreases, the number of neutrinos coming from the isotope mimics its changes. This means that by counting neutrinos, it gives an insight into the temperature change that the radioactive material is going through.

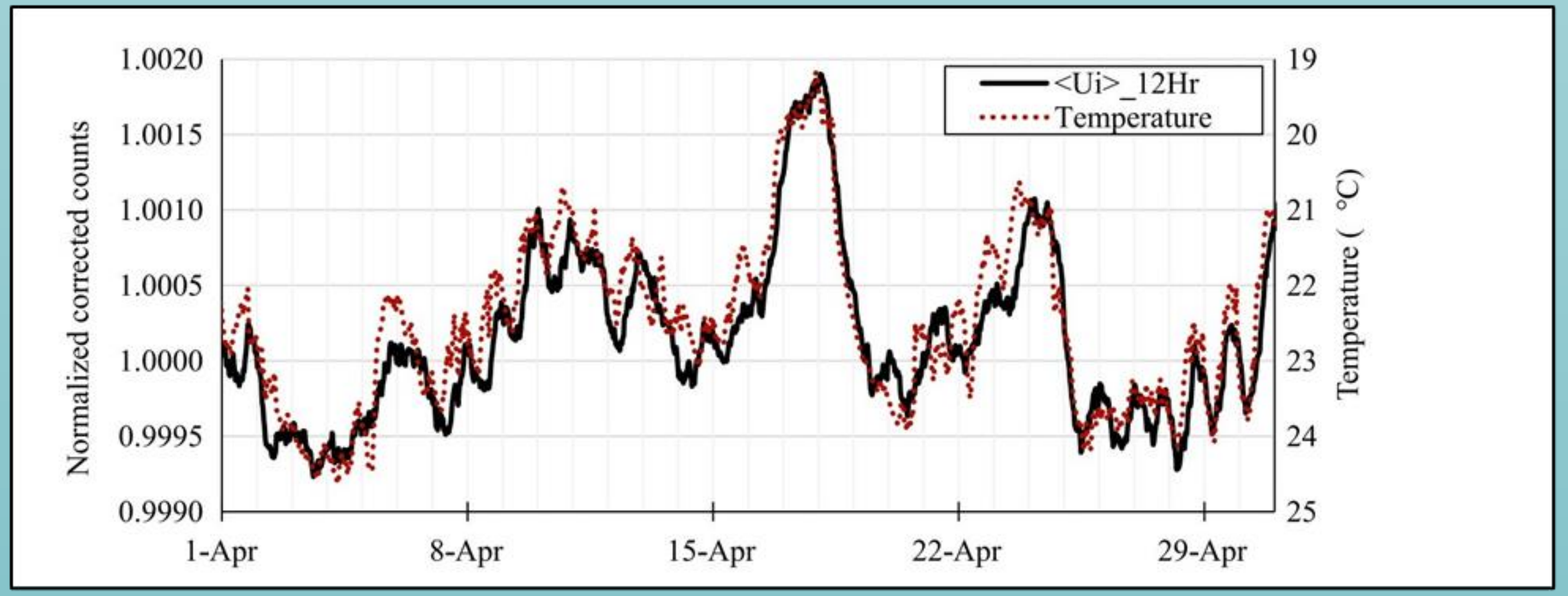


Figure 3: This is the Khalifa University of Science's results for the neutrino counting for 54Mn over a thirty-day period (Goddard et al., 2016).

The results from the experiment show how counting neutrinos is very advantageous to watching for nuclear proliferation. It shows how agencies such as the IAEA could set-up large scintillators miles away from a nuclear power plant and keep watch on the radioactive core. The scintillators would give the agency insight into if the reactor is ever stopped, since the neutrinos count would drop due to it being cooled. This information would allow them to catch anyone tampering with core, attempting to extract the 239Pu, without having to physically accesses the plant.

Conclusions

The exploration of neutrinos and how they act is an important aspect of understanding radioactive material. This experiment and others like it show how neutrinos can be used to watch for the creation of weapons of mass destruction. They have led to such programs as Project Watchman, which is based on using neutrino counting to watch for nuclear proliferation (Askins et al., 2015). Hopefully, the information experiments like this will yield away to protect the human race from burning in atomic fire

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