REACTOR NEUTRINO DETECTION USING CRYSTALS

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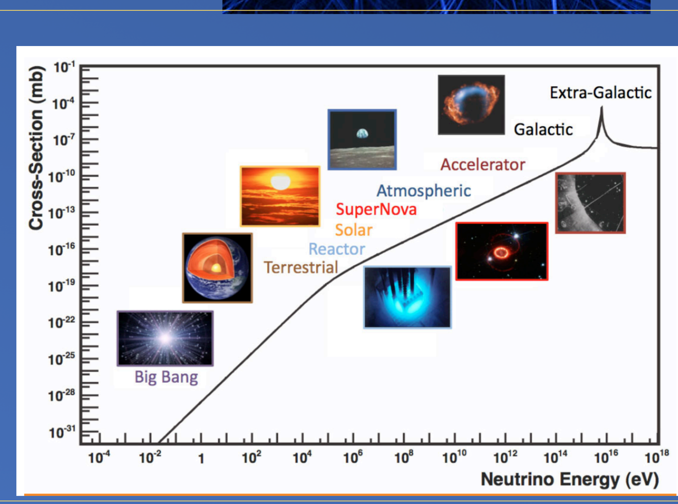
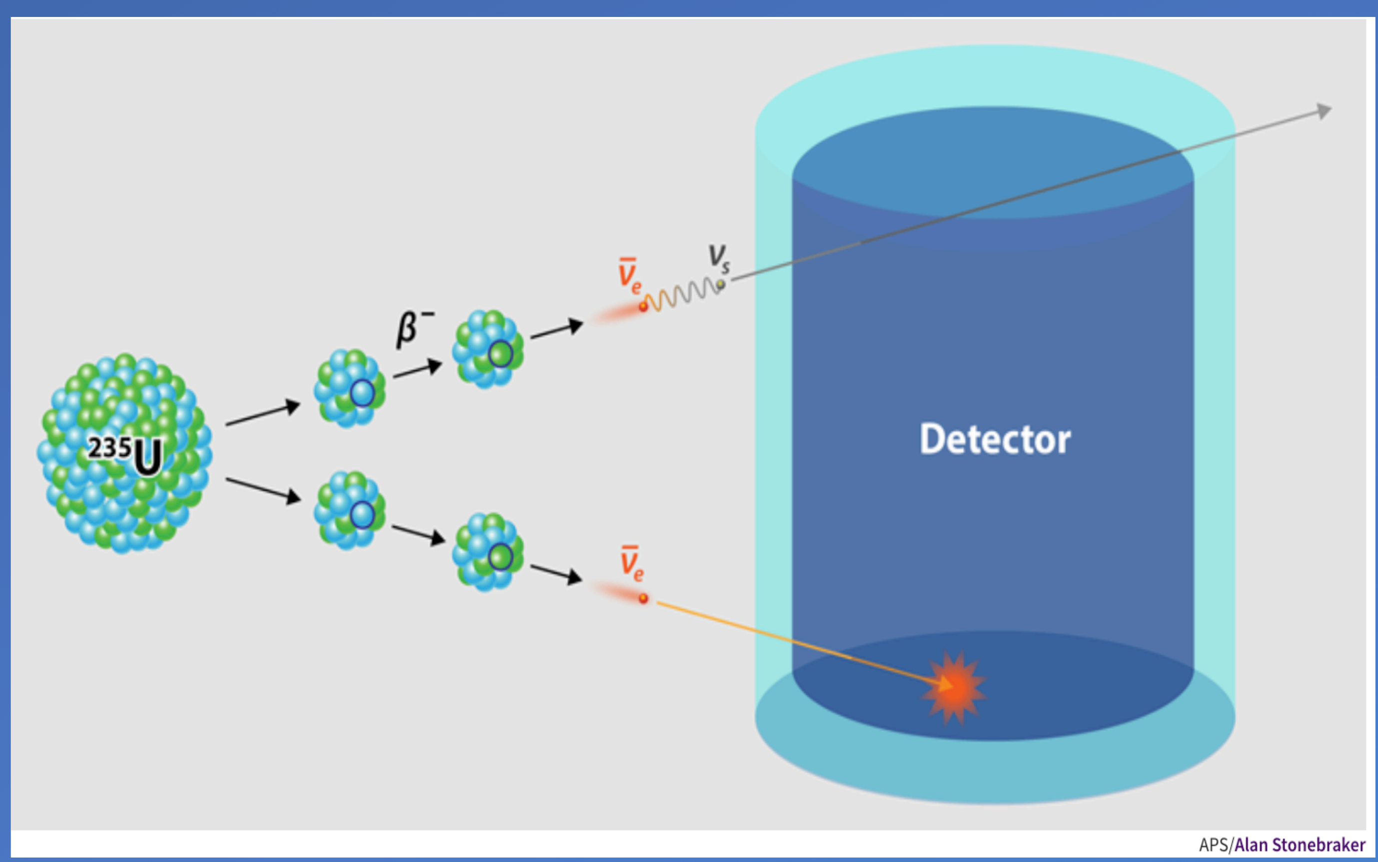
NEUTRINOS Their properties and behavior point to new physics and hold answers to deep cosmological mysteries. Yet they're are extremely difficult to detect and understand. So, innovation in detection tech is crucial to bridge the gaps in our knowledge about them. They're produced during weak decays from a wide range of sources.
in this research we focus on neutrinos produced in a nuclear reactor in a process called beta decay.

NEUTRINO SOURCES: They are produced during weak decays from a wide range of sources, such as: during a supernova, from a neutron star, from natural nuclear reactions in the core of a star, when cosmic rays strike atoms, beta decay of atomic nuclei or hadrons;there are also big bang neutrinos. In fact, any accelerated particle beams that strike atoms can produce them. Any artificial nuclear reactions in particle accelerators, nuclear bombs and nuclear reactors are also a great source of this 'ghost' particle. Here we focus on neutrinos produced in a nuclear reactor.

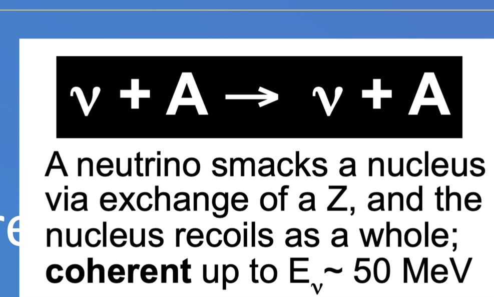




REACTOR NEUTRINOS: Reactors are incredibly useful for studying neutrinos both because they produce a huge flux of low energy neutrinos, and also because they come in only one flavor: electron antineutrinos. In particle physics, it is really great to know exactly what you are starting with so that is a big plus. Reactor neutrinos are born in a process called beta decay, which happens inside the atomic nucleus. When neutrons induce fission in uranium or plutonium for instance,, their atoms break up into lighter elements and undergo beta decay as they become more stable. Some of the energy from this interaction is carried away by neutrinos, but are not radioactive themselves. There are lots of different things scientists can measure about these outgoing neutrinos. Neutrino detectors can be positioned at a range of distances from the reactor. Different distances provide different opportunities for measurements that provide valuable information on how these neutrinos oscillate and change over an interval.

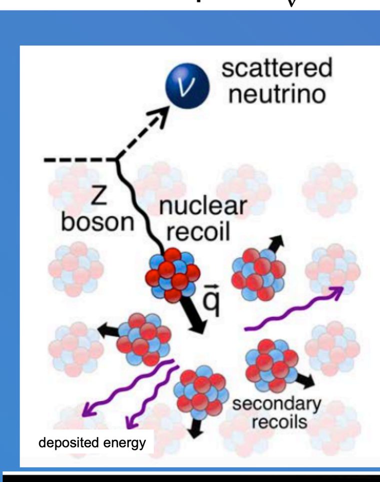
REACTOR NEUTRINOS AS A SAFEGUARD: Reactors steadily release neutrinos. If measured with precision, can be an effective indicator of reactor output over a defined time period/condition. Such measurements can be utilized as a nuclear proliferation/safeguard measure, utilizing crystal lattice defects caused by the reactor flux.

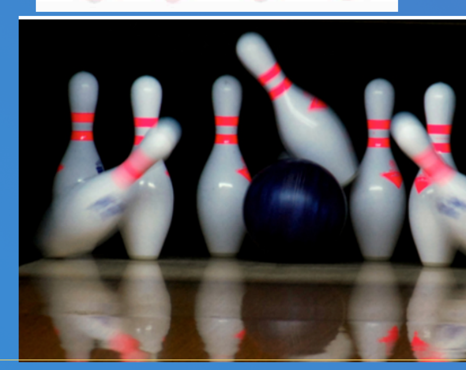
COHERENT ELASTIC NEUTRINO-NUCLEUS SCATTERING (CEνNS) Proposed in the 1970s, detected in 2017, CEνNS offer a large cross section for neutrinos, i.e. likelihood of interaction, that increases as N^2 where N is the number of neutrons in the nucleus. CEvNS events fit in well with the crystal detector technology we're exploring.

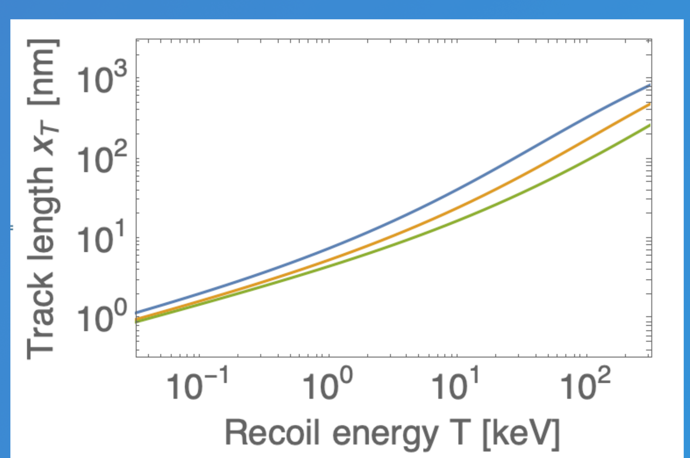


CEνNS AND CRYSTAL DETECTORS

We theorize the use of a specifically designed crystal for this purpose. Crystal Detectors have been explored as a tool for particle detection for CEνNS interactions since the mid 2010's. The elastic collision of a CEvNS type neutrino with a nucleus is expected to deposit some energies on the keV range. This energy is significantly larger than the lattice potential of typical crystals. You can think of that energy as a bowling ball striking the pins representing the crystal lattice structure. The recoiling nucleus scatters with the lattice, creating a localized cluster of damage tracks consisting of measurable vacancies. In our case, we need to research the optimal makeup of such a crystal detector to maximize precision of measurement of these reactor neutrino fluxes. Crystals develop nuclear damage tracks when particles collide with them. These damage tracks in their lattices occur in varying lengths and clusters depending on their composition.Track evolution can be singled out in data analysis after subtraction of damage tracks from background

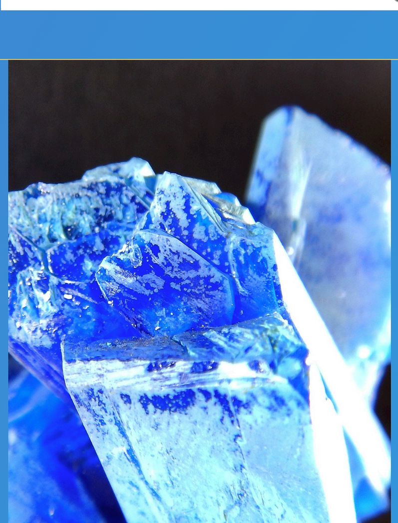






RECOIL ENERGY AND TRACK LENGTH APPROXIMATION

Linear energy transfer takes place until the incident particle's energy and speed are reduced to the same as its surroundings. The lengths of these damage tracks is almost proportional to the nuclear recoil energy, which is produced at different scales for different incident particles. So, based on the type of particle, this energy range is quantifiable, which means that tracks can be used to study CEνNS interactions with unprecedented precision for reactor neutrinos



CRYSTAL SELECTION CRITERIA : Exploring a range of compounds and their nuclear recoil spectra is necessary to facilitate detector optimization. Comparing each spectrum to the corresponding neutron background from incoming cosmic ray flux, the main source of noise is also crucial.

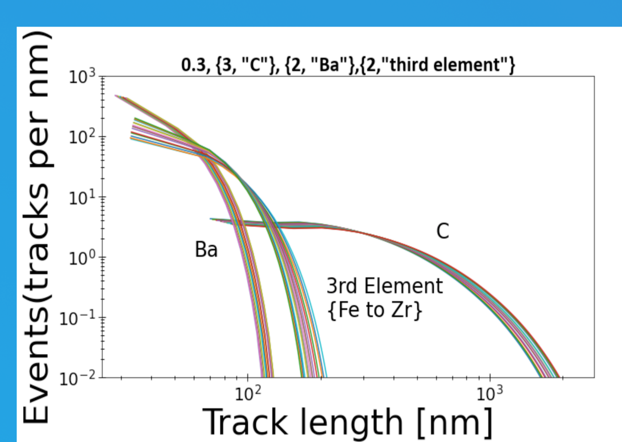
SUMMARY OF RESULTS SO FAR

Events per track length are much higher for heavier crystal elements. The crystal damage events per track length do not change too drastically for different atomic configurations of any combination. Track lengths for a crystal compound are directly proportional to its density..

FUTURE SCOPE OF RESEARCH

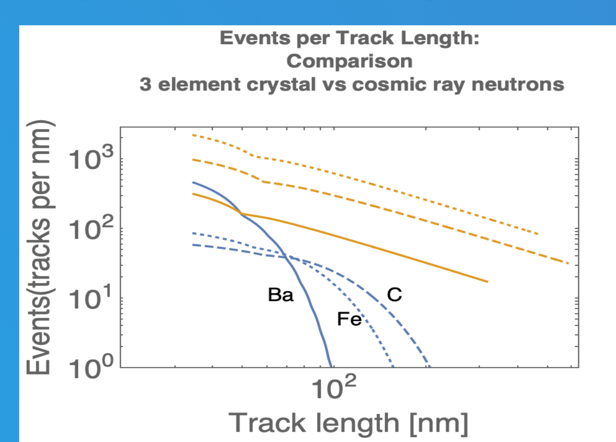
Crystal design requires a thorough analysis of a wide range of compound makeup. Exploring crystal properties which allow for a minimal background neutron cross section is cruciall to design the optimal detector for CEvNS neutrinos. Once we characterize the appropriate properties for a hypothetical crystal, the next step is to call on material science experts to determine its feasibility

An example crystal nuclear recoil track analysis



Hypothetical crystal consists of C, Ba, and a third element from Fe-Zr

Cosmic ray neutron background and CEvNS spectrum comparison



Hypothetical crystal made of a combination of C, Ba, and Fe atoms