SAND2014-0101P

An Overview of Neutrino Detection

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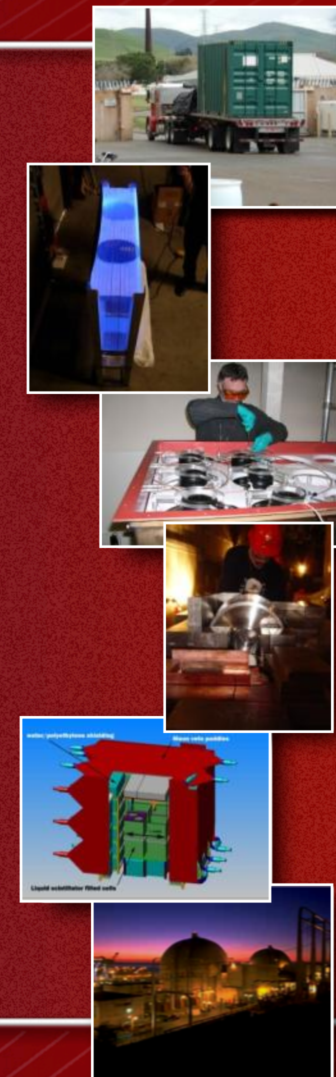

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Neutrinos are a “young” Field

- First dreamed up in 1930 as a mythical particle that is unseen but carries away energy from beta-decay
- Only first detected in 1960 by the reverse process
- There are only three types (flavors)
  - the last one was experimentally verified in 2000
- Neutrinos and antineutrinos are only distinguished by certain quantum numbers (and the allowed reaction products)
  - Antineutrino = neutrino going backwards in time

We Live in an Electromagnetic World (plus gravity)

- All interactions that we experience are Electromagnetic
  - Macroscopic interactions, chemical bonds, atomic bonds
- All detectors require Electromagnetic interactions
  - Scintillators produces light (which is EM radiation) from EM interactions
  - Charge collection detectors are drifting electrons that have been liberated through EM interactions
    - Ge, He-3, Geiger counters, CCDs, PMTs, etc.
- Neutrinos do not interact through any EM interactions. They only have two types of interactions
  - Charged Current Interaction – “Neutrino is eliminated”
    - Leaves behind more conventional products that can be seen
  - Neutral Current Interaction – “Neutrino bounces”
    - Outgoing neutrino is invisible as it carries away energy
    - We can only detect the recoil of whatever it hit

A Diversity of Neutrino Detector Technologies

- Scintillator based with/without neutron capture agents
  - Reines and Cowen through KamLand, Double Chooz, etc.
- Water based using Cerenkov signature
  - IMB, Super-Kamiokande, SNO
  - Only SK and SNO have looked at neutral current so far
- Radio-chemical conversion
  - Homestake/Chlorine, GALLEX, SAGE
- Each method has different backgrounds and sensitivities
  - Scintillator has highest detection capability, but also highest background sensitivity
  - Radio-chemical is “quiet” but very low probability
- Coherent scatter is a neutral current interaction with high rates, but small signals – capability not yet achieved
  - Interacts with every neutron in the nucleus simultaneously
  - Leading technologies: Ge, LXe/Ar, CsI (at high energies), Si
    - Limitation is sensitivity to low energy recoils

Specifics of Reactor Antineutrinos

- Constrain available technologies that might apply
  - Low energies eliminate some interactions
  - Antineutrino specific final states
- Specifics of background considerations
  - Generally high-background environments
    - Shallow depths have high cosmic induced backgrounds
    - Reactor correlated neutrons and gammas
- Technologies that have been used to date
  - Scintillators (liquid and plastic) have provided the only successes
  - Inability to sufficiently reduce backgrounds have limited all others
- Detector choices depend on desired information/ timescale

Difference between Basic Science and Safeguards Applications

- Basic science has some luxuries
  - Creating optimal environments for measurements
    - Deep mines, low-background shielding
  - Long timeframes to adapt to unforeseen situations
  - Many hands to do careful calibrations and investigate very small signatures
- Operating in less favorable conditions requires
  - Understanding elevated background environments
  - Creative ways to avoid or discriminate backgrounds
  - improving detector technologies to provide additional information or sensitivity capabilities
    - Ex: segmentation provides worse calibration uniformity but provides 3-4 orders of magnitude background rejection
    - Directionality would be very useful to SG, but not very important for basic science