The Deployment of Three Prototype Detectors for Reactor Monitoring and Safeguards

Current Reactor Safeguards

- IAEA and Other Safeguards are Designed to Detect Diversion of Fissile Material (Plutonium, HEU) from Civil Fuel Cycles
- Reactor
- Onsite Fuel Storage
- Reprocessing
- (months to years)

Reactors and Antineutrinos

- Liquid Scintillator
  - About 6 antineutrinos are emitted after each fission
  - Antineutrino rate and energy spectrum are sensitive to the isotopic composition of the reactor core
  - Detection rates near reactors are high:
    - e.g. 0.64 ton detector
    - 25 m from 3.5 GWth core
    - 3800 events/day for a 100% efficient detector

- Water Cherenkov
  - To demonstrate the feasibility of this technique we have deployed several detectors at SONGS
  - (San Onofre Nuclear Generating Station)
  - The detectors is located in the “tendon gallery” of SONGS Unit 2, an ideal location
  - outside containment
  - Rarely accessed for plant operation
  - only 25m from the reactor core
  - provides 20 mwe overburden

Conclusions

1. Antineutrino detectors can be used to monitor nuclear reactors remotely and non-invasively – this has been established by prior physics experiments and is being confirmed by us with several practical devices.
2. The technology may fill an important safeguards niche, IAEA has expressed strong interest
3. Ongoing Effort:
   - Improve deployability through materials choices
   - Increase range of possible deployment locations by developing devices that can work closer to the surface

Liquid Scintillator

- Our first deployment used 0.6 tons of Gd doped liquid scintillator - a proven reactor antineutrino detection technology.
- This device was very successful, but deployment of the slightly flammable scintillator placed some burden on the reactor operator
- Simple, homogeneous design
- Relatively good energy resolution
- High neutron capture fraction on Gd

This device clearly observes reactor power changes and fuel evolution

Plastic Scintillator

- The liquid scintillator detector was very successful, but the detection medium was less than ideal from the point of view of the reactor operator and the safeguards community. Therefore, we investigated a solid state alternative based upon plastic scintillator slabs interleaved with a Gd coated sheets
- 40% Reduction in combustible inventory
- Lower neutron capture efficiency on Gd
- No leakage or flammable vapour concerns
- No transportation of hazardous material required
- Preassembled

This device clearly observes reactor outages

Water Cherenkov

- Another path towards deployable devices that we are following is the use of a Gd-doped water Cherenkov detector. A 0.25 ton (unshielded) prototype has been deployed at SONGS.
- Non-flammable, non-combustible
- Less expensive material and ES&I overhead
- Largely insensitive to proton recoils (major correlated background)
- Very low light yield, poor energy resolution, forces high e+ threshold

Water Cherenkov

- This device is clearly sensitive to neutrons and correlations, but we are yet to observe reactor antineutrinos

IAEA and Other Safeguards are Designed to Detect Diversion of Fissile Material (Plutonium, HEU) from Civil Fuel Cycles

1. Check Input and Output Declarations
2. Verify with Item Accountability
3. Containment and Surveillance

Operators Report Fuel Burnup and Power History

No Direct Power History Measurement is Made
No Direct Plutonium Inventory Measurement Until Reprocessing

Compact antineutrino detectors could provide continuous, non-intrusive, unattended measurements for safeguards regimes

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