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The Safeguards Detector at SONGS

A Sandia and Lawrence Livermore National Laboratories Joint Project

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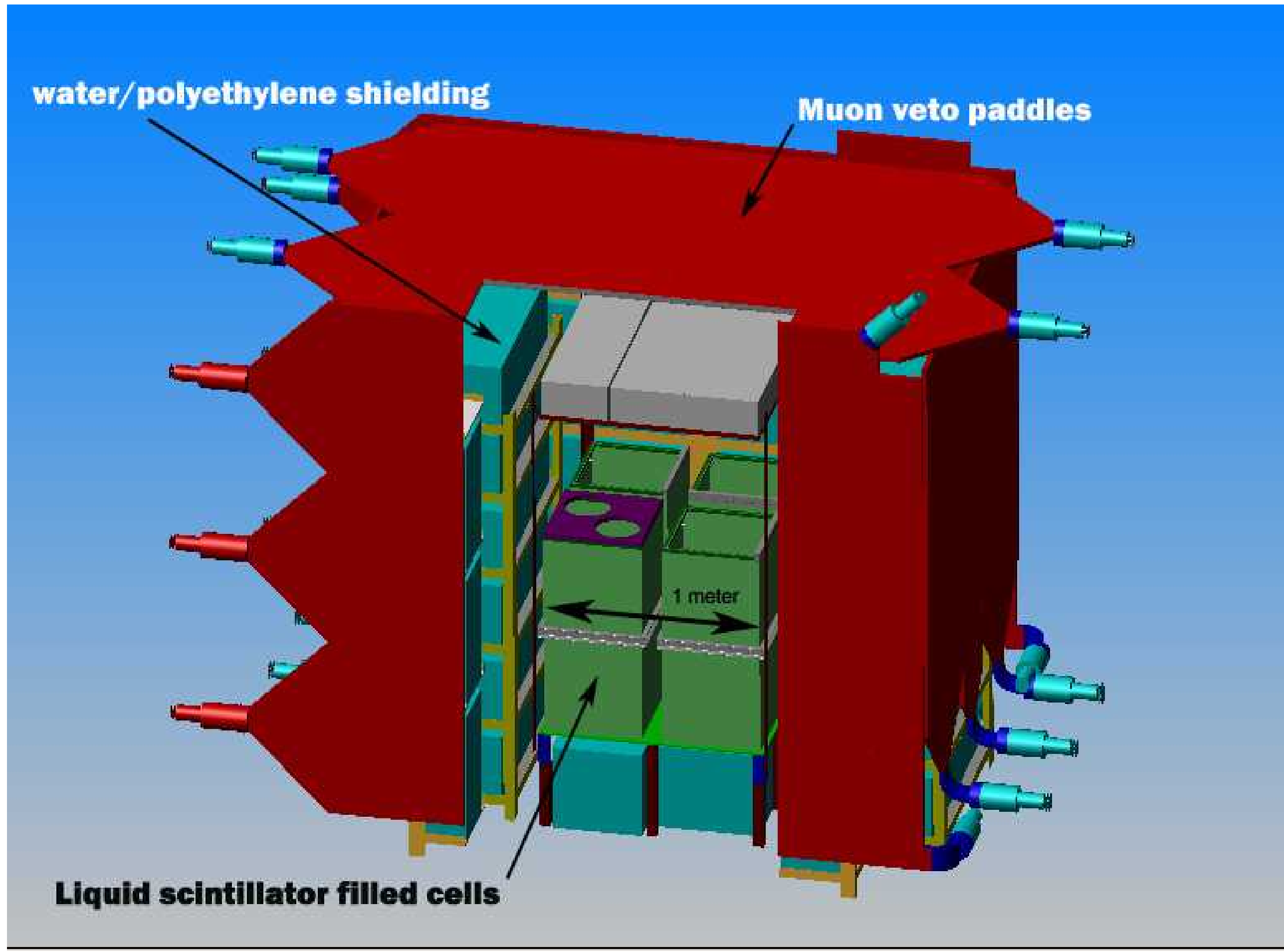
Design Principles

- **Simple, inexpensive, robust**
  - **Incorporate *proven* state of the art at the time**
    - **Antineutrino detection via inverse beta decay**
    - **Gd loaded scintillator**
    - **"Onion" style detector – central target surrounded by various shielding layers**
  - **Physically robust for reactor environment (e.g. steel scintillator vessels)**
  - **Modular for manhole access**

Sandia/LLNL Antineutrino Detector

- **Detector system is…**
  - **0.64 ton Gd doped liquid scintillator readout by 8x 8” PMT**
  - **6-sided water shield**
  - **5-sided active muon veto**
  - **Taking almost all of the space in the tendon gallery between the inner and outer walls**



Cell Design

- Stainless tanks – no scintillator attack
  - Tank size determined by manhole size
- PMTs coupled to scintillator by acrylic plugs and mineral oil
- Light reflectors are argon filled PTFE bags (Bugey)

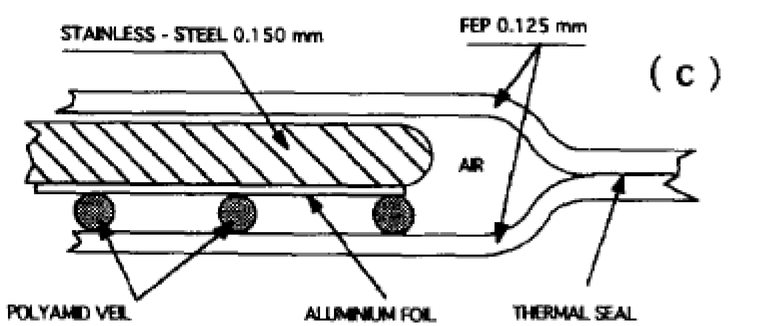
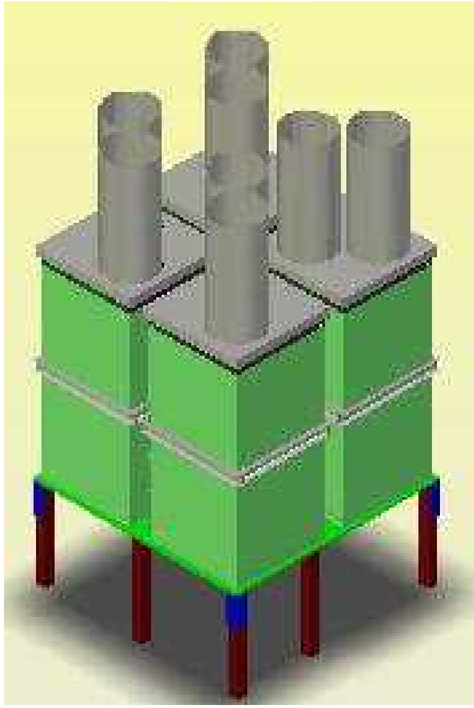


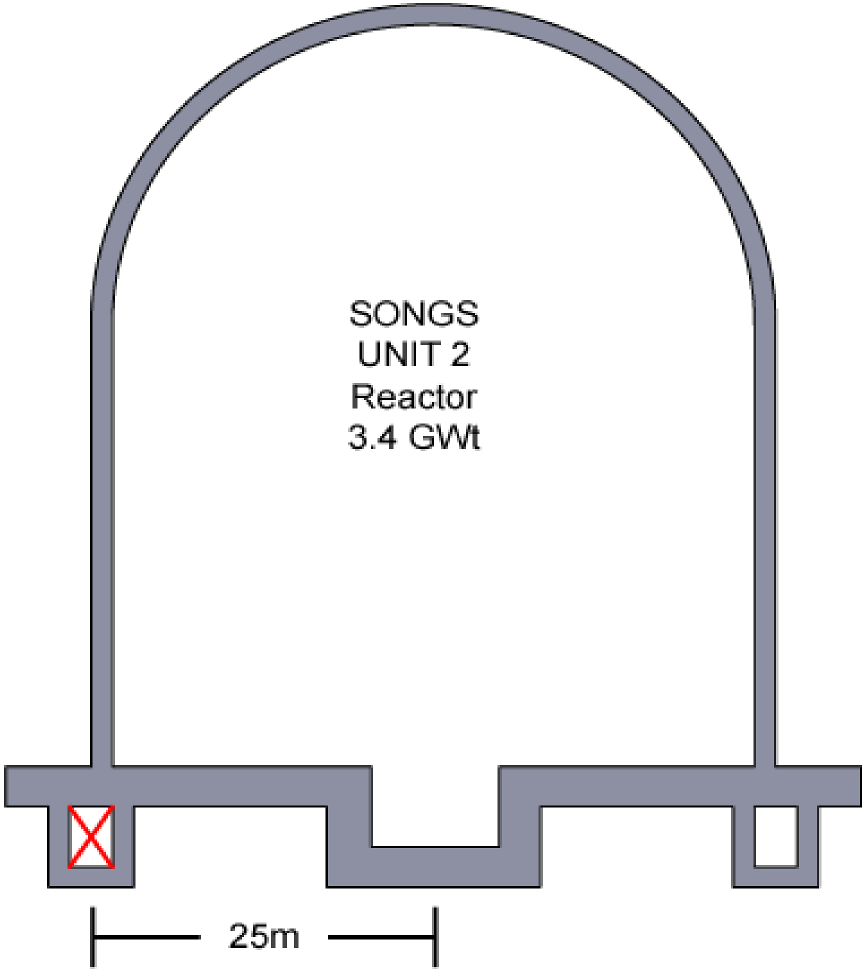
Fig. 3. Main features of a light-collector: (a) Dimensions. (b) Detail of the overlap after folding. (c) The components of a reflector wall. The total thickness is 0.6 mm.



Prototype deployment – San Onofre Nuclear Generating Station

San Onofre Nuclear Generating Station Unit 2 Tendon Gallery

- Tendon gallery is ideal location
  - Rarely accessed for plant operation
  - As close to reactor as you can get while being outside containment
  - Provides ~20 mwe overburden
- 3.4 GWt => 10^{20} ν / s
- In tendon gallery with ~10^{17} ν / s per m^2
- Around 4000 interactions expected per day

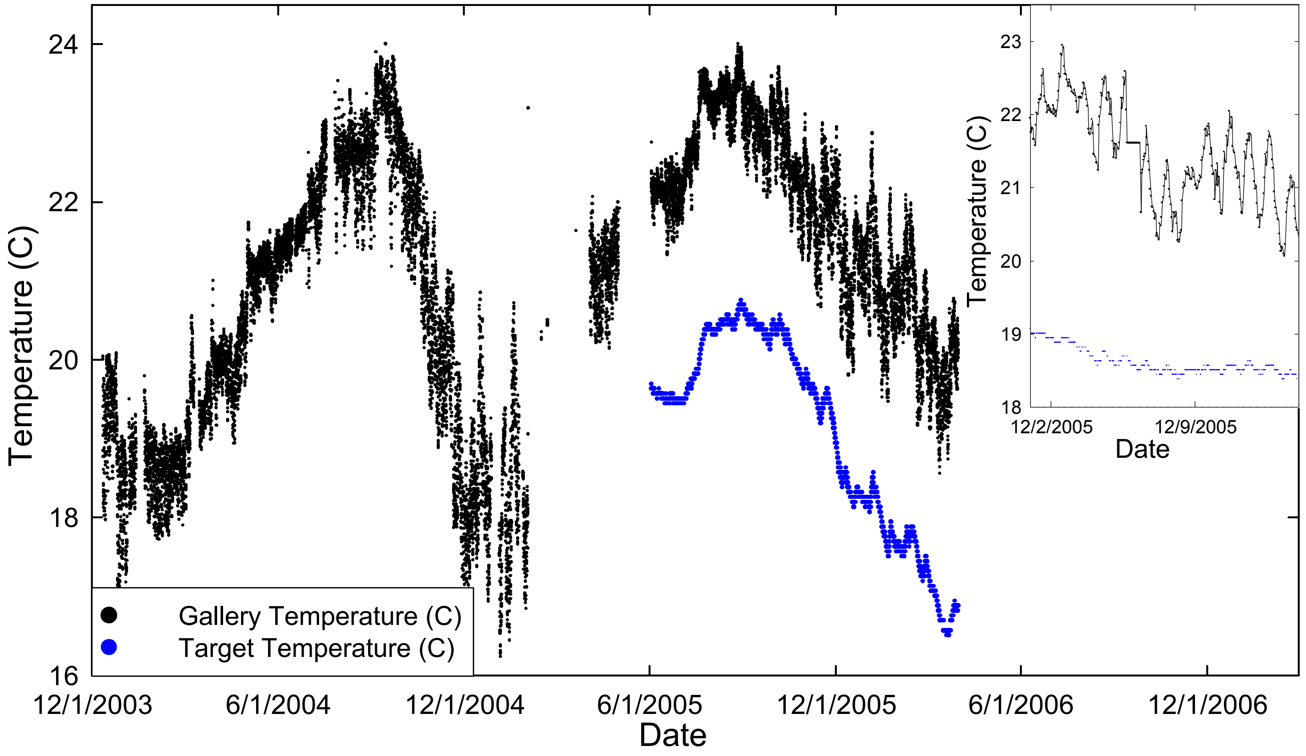


Installation at SONGS

Installation at SONGS

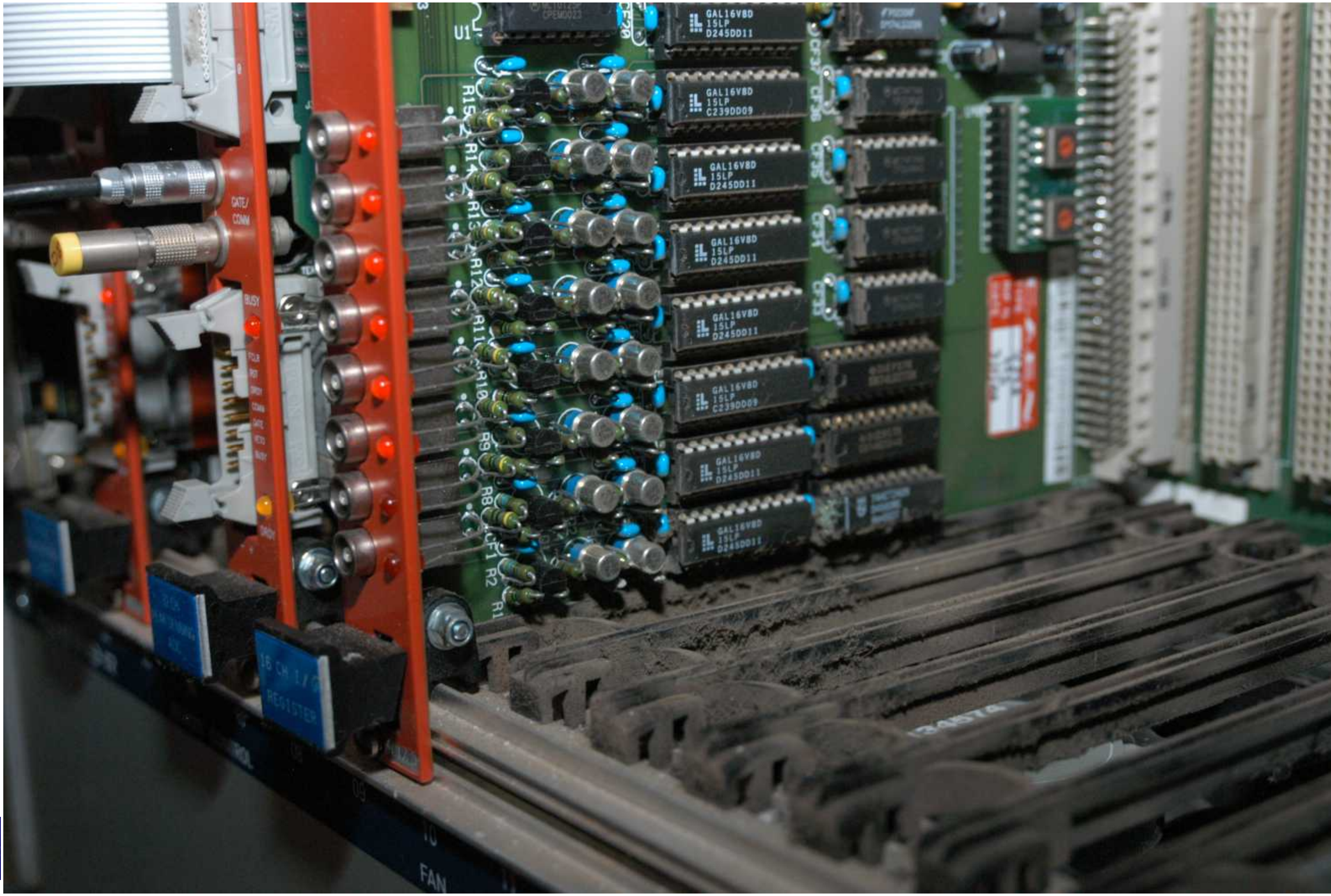
Environment

- **Electronics exposed to diurnal and seasonal temperature change, time scale for target is longer**

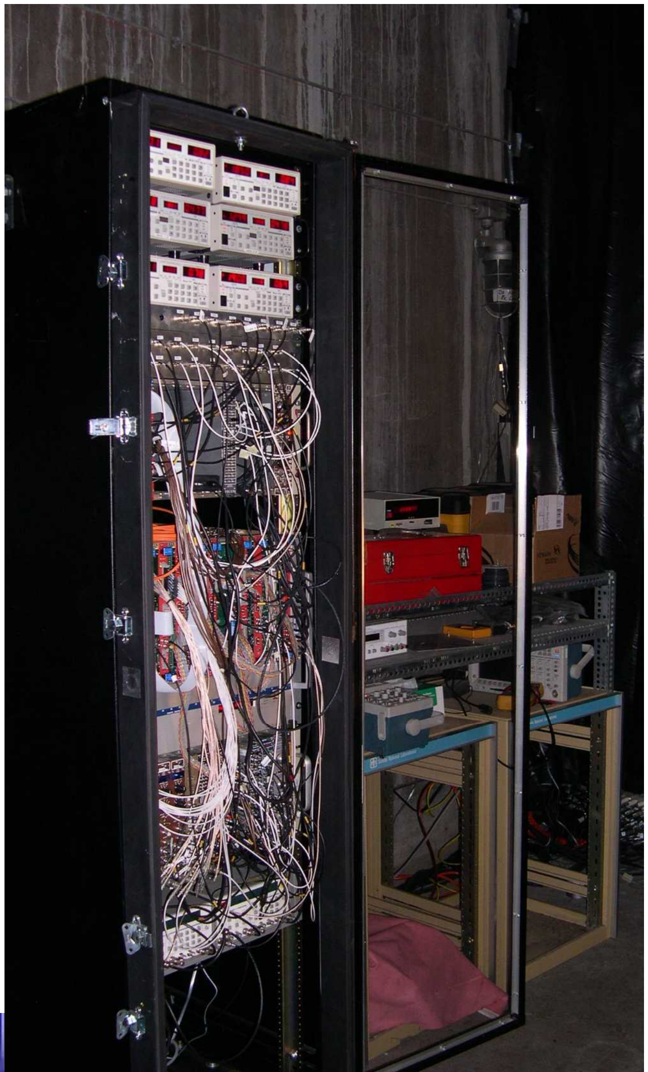


Environment

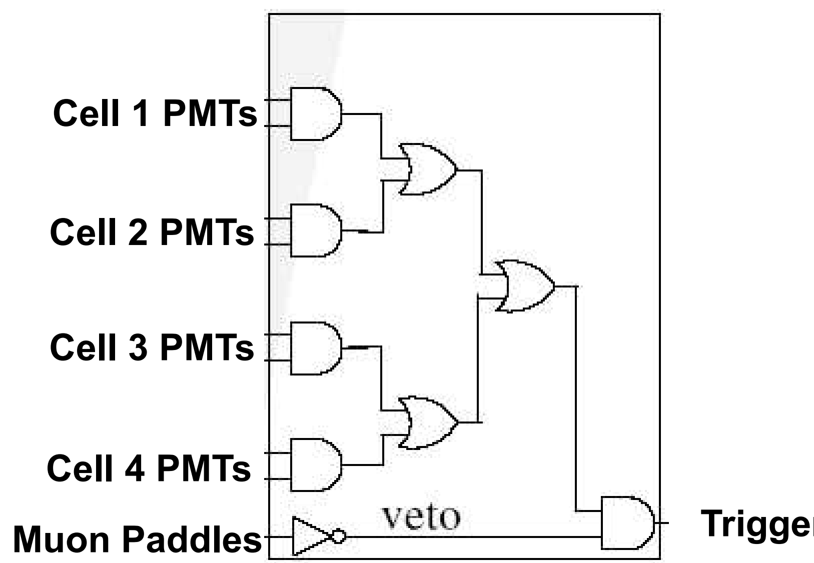
• **Atmosphere is dusty, oily, and corrosive**



DAQ

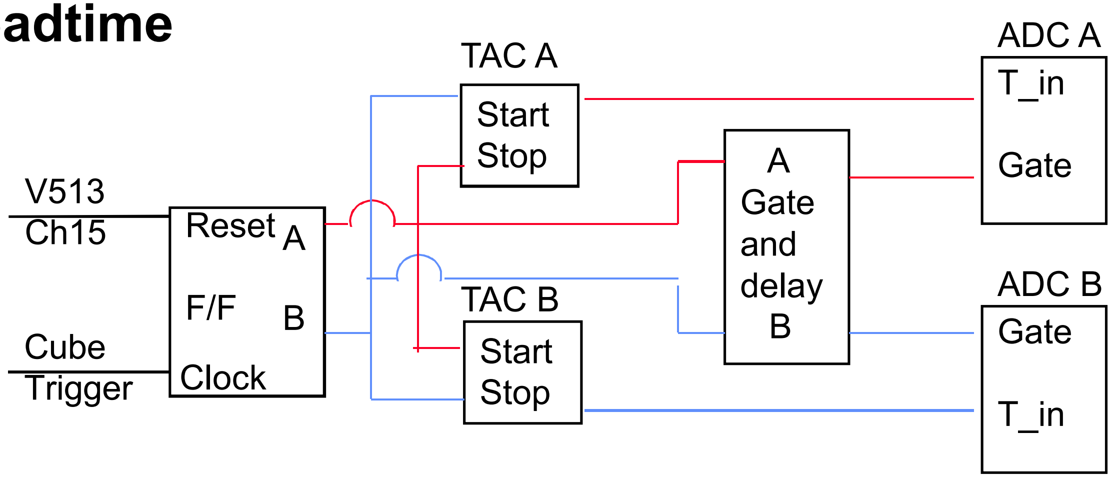


- Based on NIM/VME components – again goal is for a simple system using available equipment
- Trigger formed from coincidence of two PMTs on each cell
- A hardware veto of 20μs is applied after passage of a muon



DAQ

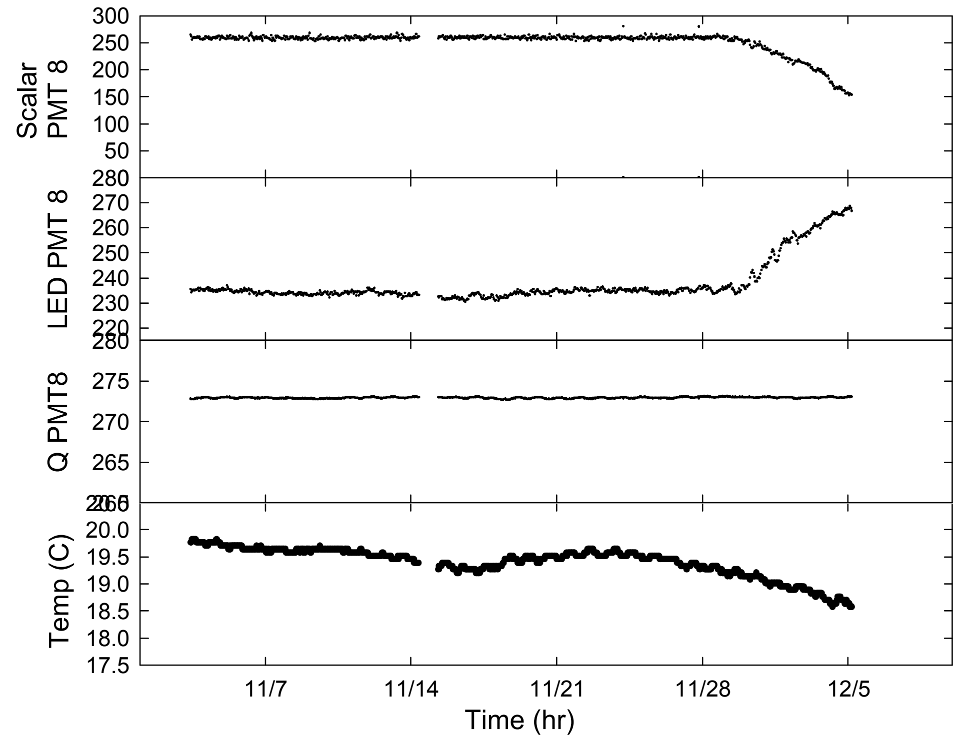
- **We alternate between pairs of ADCs and TACs to reduce deadtime**



- **For each trigger we measure :**
  - **Outputs of all PMT**
  - **Interevent time**
  - **Time since last muon**
- **Events are streamed to disk for later analysis**
- **We have developed FPGA based implementations of the DAQ, which we hope to install in the future**

LED and Charger injectors

- We have recently installed charge injectors on the PMT preamp, and LEDs to the "cookies"
- Allow us to isolate gain changes, but not calibrate since LEDs are not temperature stabilized
  – Observed gain changes are in the PMT/scintillator system, not the electronics chain



Unattended Operation

- All systems automated
  - Calibrations
  - State of Health (scalars, LED, temperature, etc)
  - Reduced data uplink
  - Analysis
- Only manual operations are hand carry of raw data and periodic AmBe calibrations
  - This is a crucial feature since to reduces our "footprint" from the operators point of view

Conclusions

- We have successfully deployed a relatively simple antineutrino detector
  - inside the “Protected Area” at an operating commercial reactor
  - With no burden or disturbance to plant operation
  - In a challenging physical environment
  - Operation is automated
  - Operation is remotely monitored and can be remotely controlled