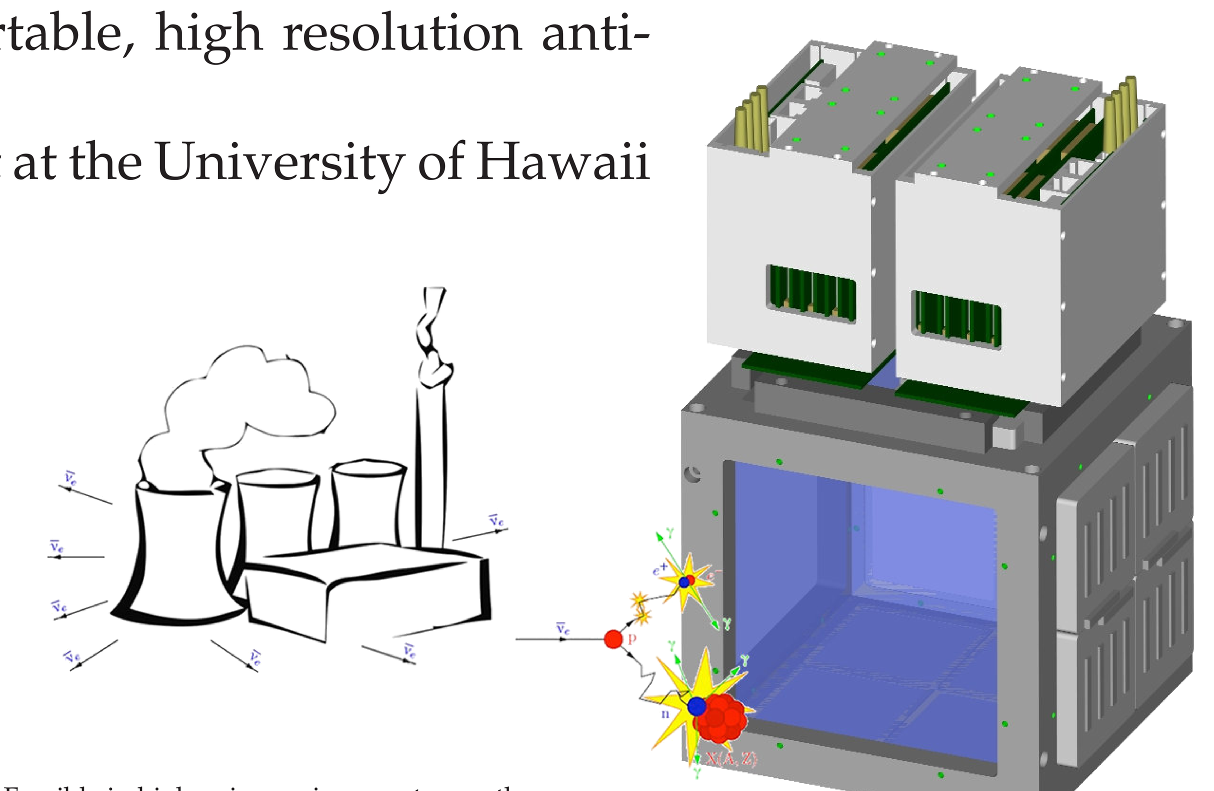
mini Time Cube

(UHM): S. Smith, A. Carpenter, R. Dorrill, M. Duvall, S. Dye, J. Learned, V. Li, L. Macchiarulo, S. Matsuno, S. Negrashov, L. Ritter, M. Rosen, M. Sakai,
(IAI): B. Dobbs, G. Jocher, C. Mulliss, **(NGA):** S. Usman,
(UMD): K. Engel, W. McDonough, L. Stevens, **(NIST):** P. Mumm

Summary

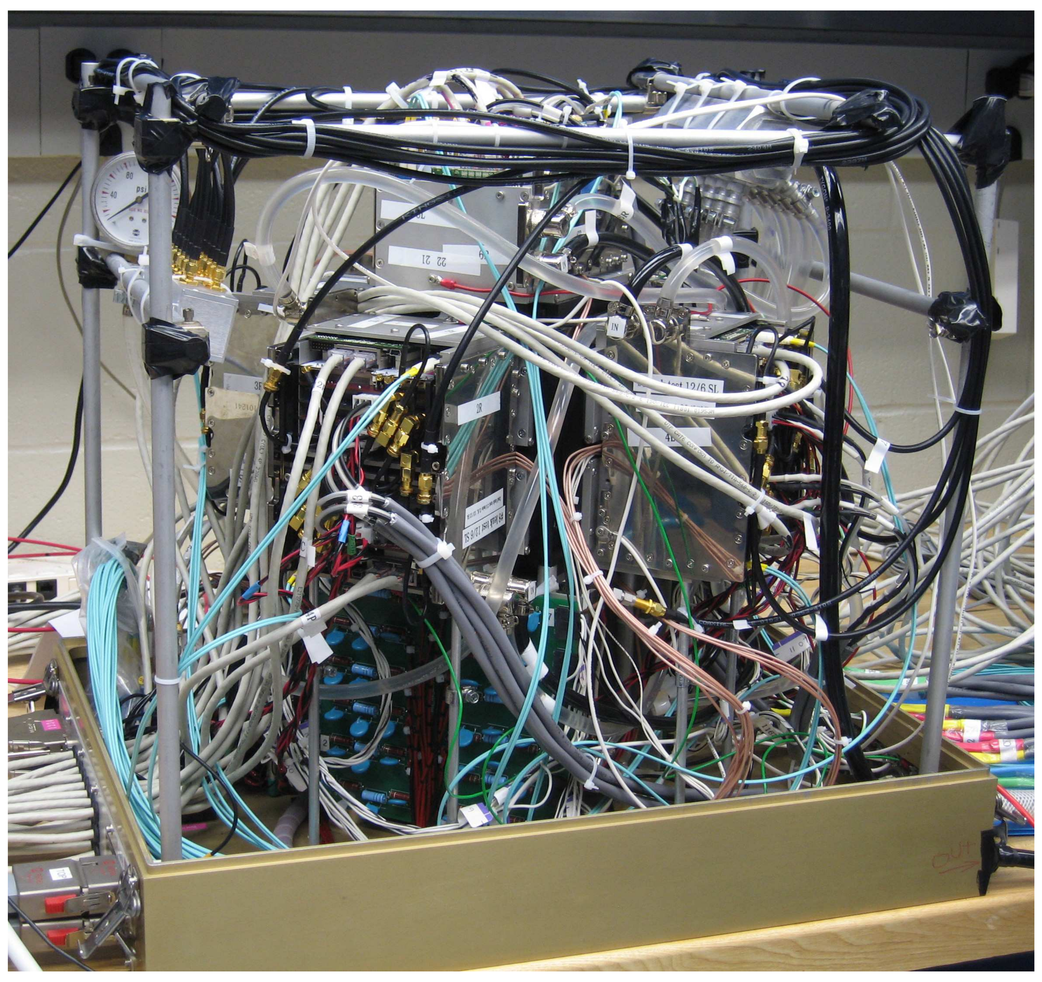
The mini Time Cube (mTC) is a small, portable, high resolution anti-neutrino detector
currently under construction and development at the University of Hawaii at Manoa.

- At the heart of the detector is a 13 cm wide cube of plastic scintillator.
- For the initial construction, we've chosen a 1% natural Boron-loaded (0.2% B^{10}) plastic scintillator from Eljen Technologies (EJ-254).
- Small size allows positron annihilation gammas to escape, which permits precise positron creation point reconstruction
- 24 Microchannel Plate PMTs, for a total of 1536 pixels
- Fast pixel timing (<100ps) and fast pipeline processing of waveforms rejects background in real time–no need for shielding.
- Neutrino directionality via mm precision reconstruction of positron production and neutron absorption locations.



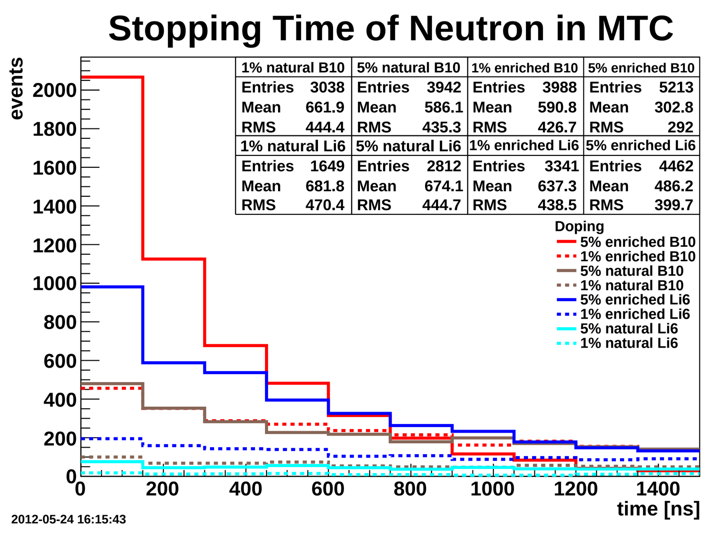
- Feasible in high noise environment, near the reactor vessel, at surface (eg. in a truck).
- Applications range from high precision measurements of radioactive materials in the Earth, to reactor neutrino oscillation studies.

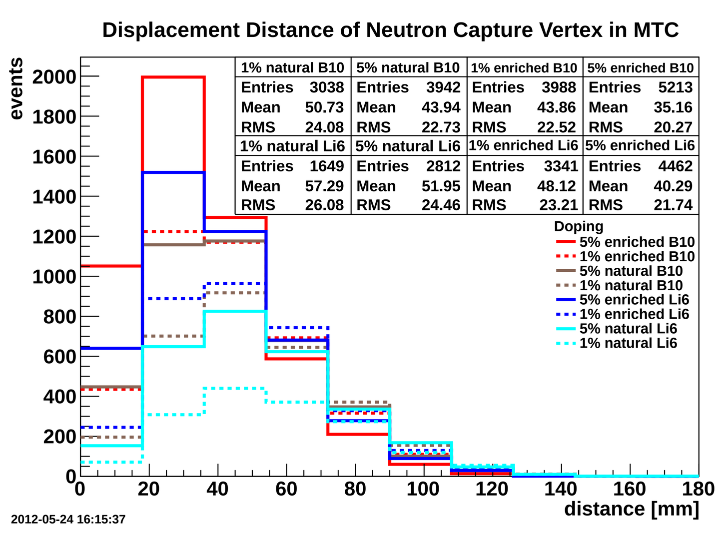
mTC at NIST

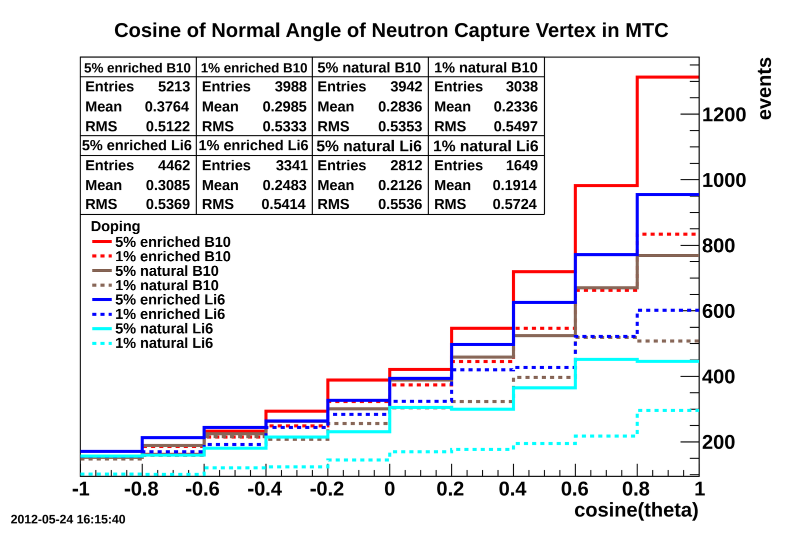


Neutron Capture

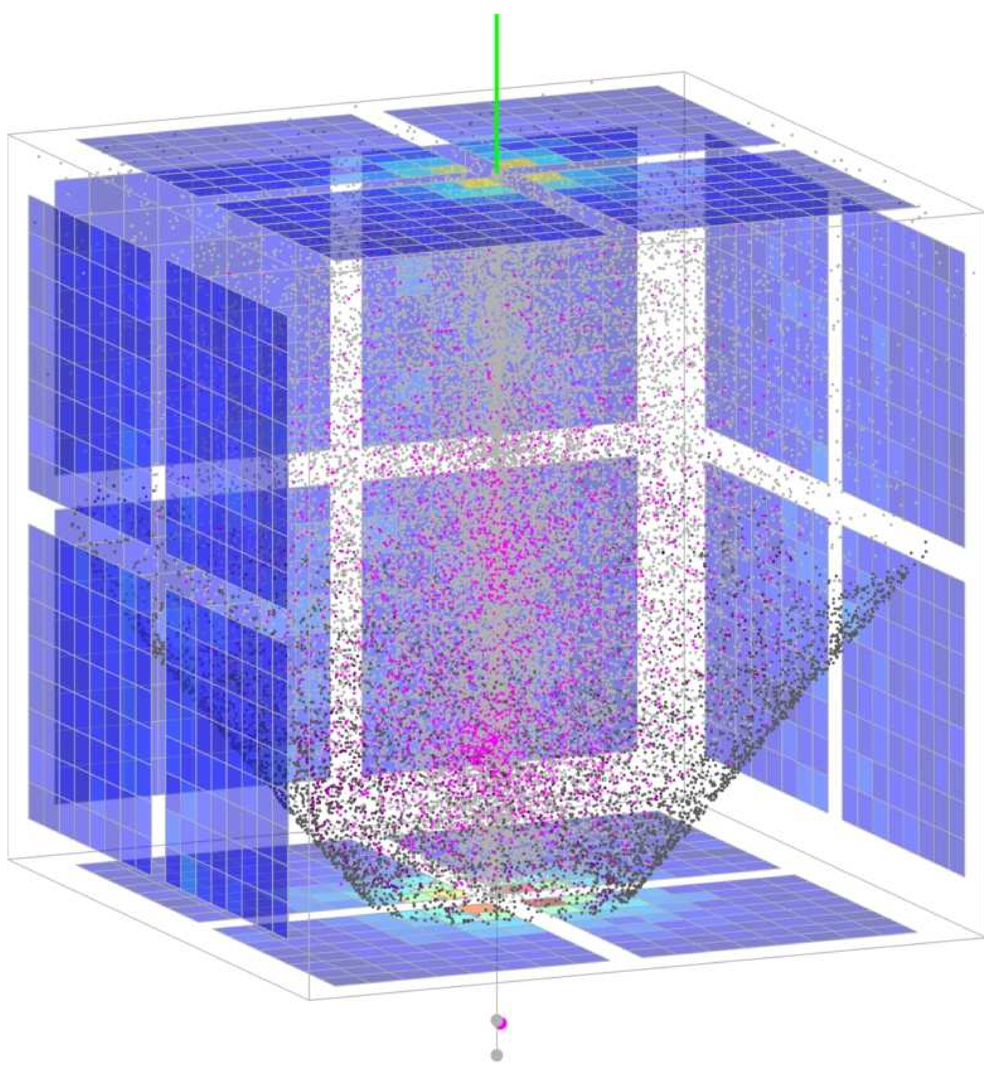
- Neutrinos interact with the detector via inverse beta decay reaction
- This produces a neutron, which loses energy through elastic collisions before being captured.
- A series of collisions leave the neutron with little directional information.
- Li^6 or B^{10} can help capture the neutron faster, in a shorter distance, to preserve as much directional information as possible.
- At similar concentrations, B^{10} outperforms Li^6 for faster capture times, shorter capture distance, and most true pointing neutron direction (see figures below).



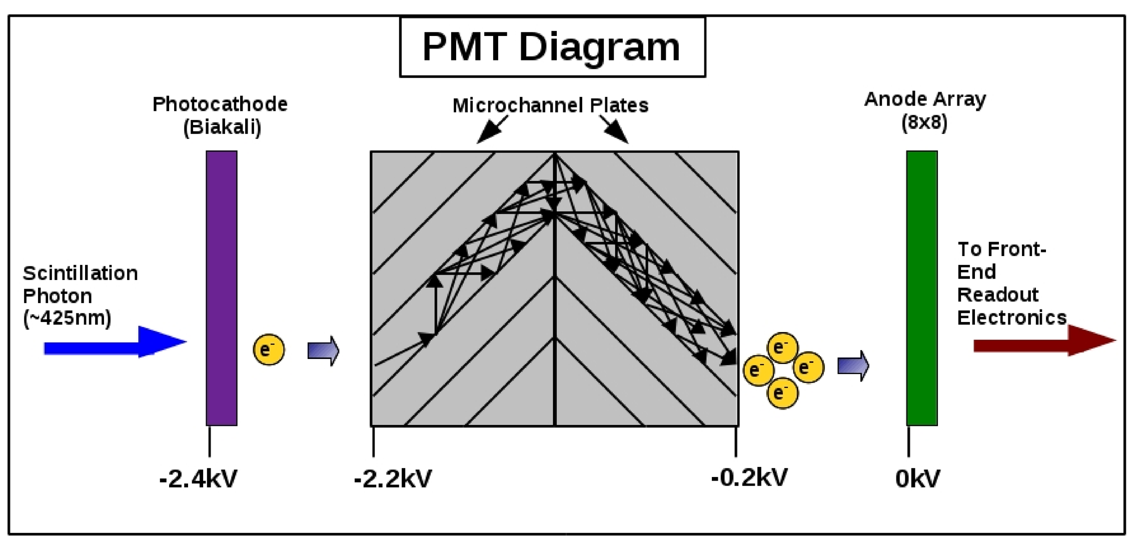




Geant Simulation



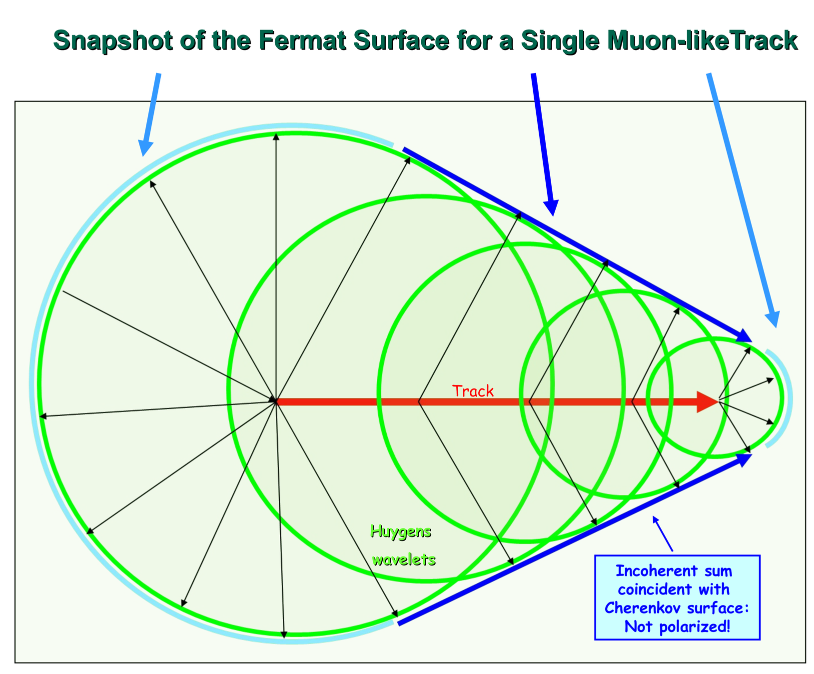
Microchannel Plate PMTs

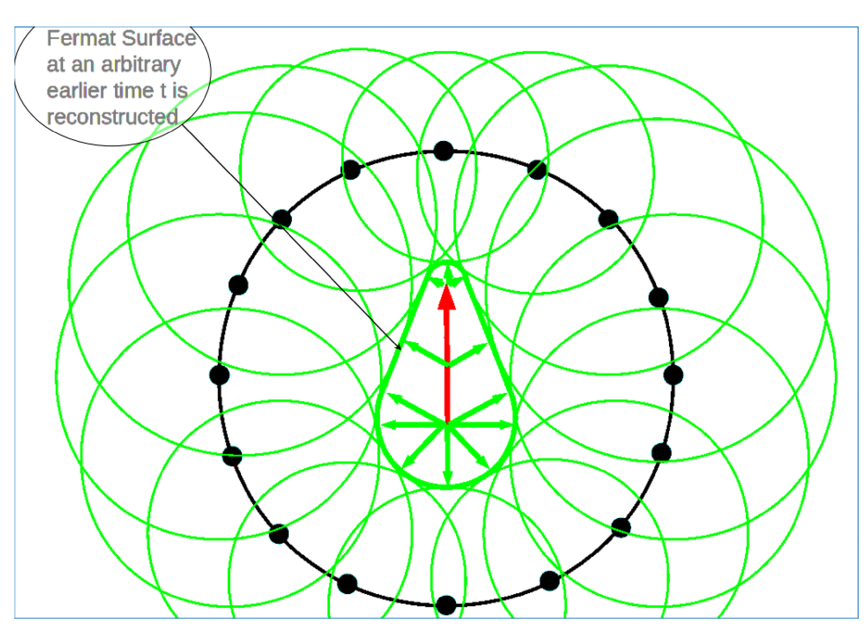


- The Planacon XP85012 Microchannel Plate (MCP) photomultipliers (PMTs) each have an 8 x 8 array of pixels, a rise time of 0.6ns, a pulse width of 1.8ns, and transit time spreads of 5ps for multi-photon events
- Photoelectrons produced by the cathode are propelled through an array of tubes called a microchannel plate.
- Two back-to-back plates create a chevron pattern that eliminates feedback to the cathode.
- The mTC has 24 MCP PMTs, for approximately 68% photodetector coverage.

Directionality

- A charged particle moves through scintillator, emitting light isotropically.
- The fastest photons to propogating away from the track will lie along the Huygen's wavelets.
- First hit times in each pixel can reconstruct the positron track, as well as the neutron capture point.
- This gives us a good estimation of the incoming neutrino direction.





Electronics

- The electronics for the mTC are being designed at the Instrument Development Lab at the University of Hawaii [?].
- Custom designed digitizing ASIC, the Ice Radio Sampler (IRS3)
- Sub-nanosecond sampling for all channels.
- Power consumption <0.3W per channel.
- Low power extraction DSPs.
- Optimized for portable operation.

References

[1] John G. Learned, *High Energy Neutrino Physics with Liquid Scintillation Detectors*, arXiv:0902.4009
[2] http://www.phys.hawaii.edu/~idlab/