Lawrence Livermore National Laboratory

Neutrino Oscillation Physics at LLNL: Double Chooz and a New Short Baseline Physics Opportunity

N. Bowden, A. Bernstein, T. Classen, S. Dazeley, G. Keefer

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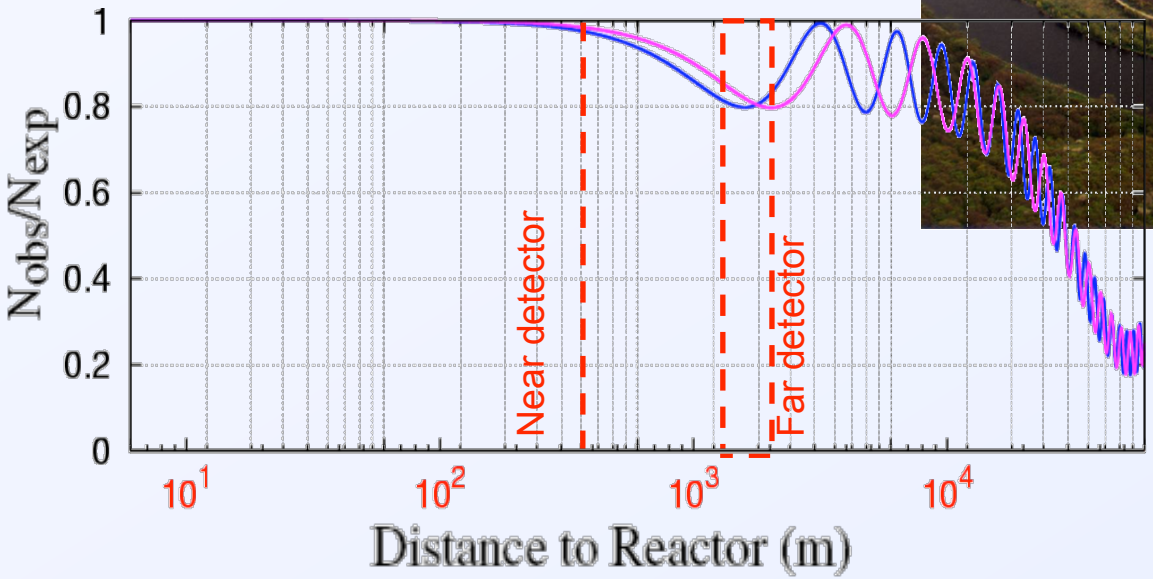
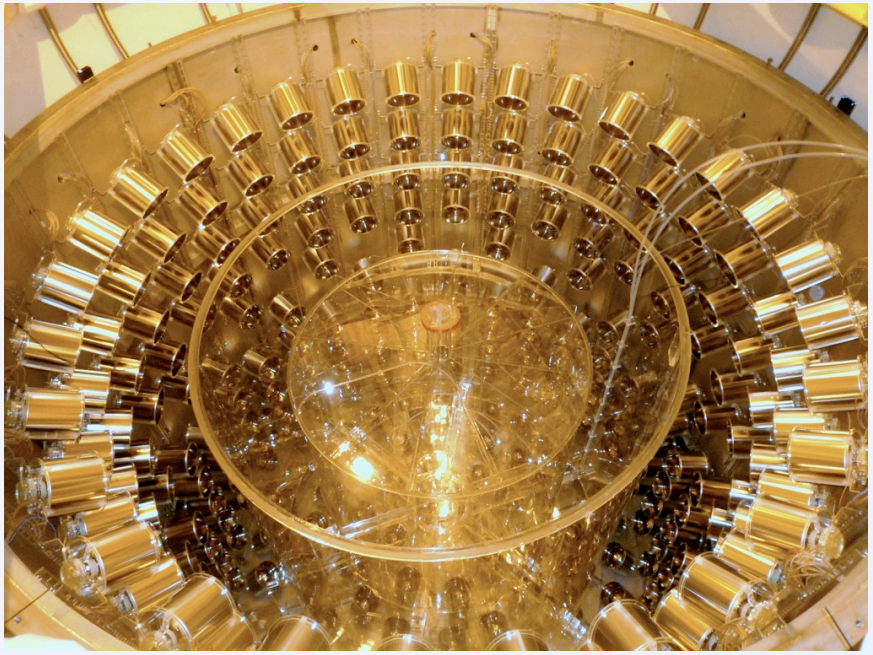
Double Chooz – A θ_{13} neutrino oscillation experiment

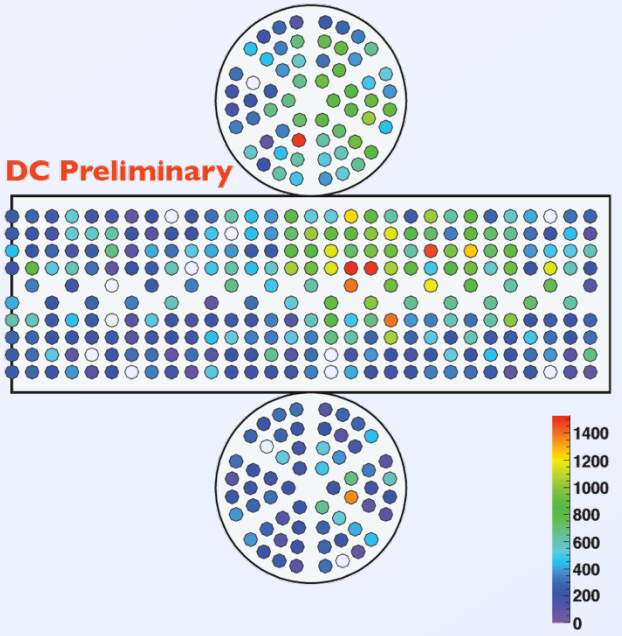
- Double Chooz will attempt to observe electron antineutrino disappearance due to θ_{13} :
  - First, using a “Far” detector,
  - Followed by, both “Near” and “Far” detectors



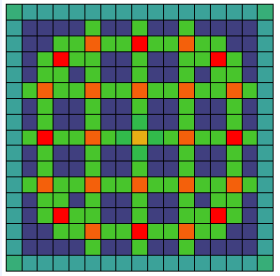
LLNL has participated in Double Chooz since 2005 – primarily supported by LDRD

- Aside from our strong interest in the oscillation physics being probed by Double Chooz, there is considerable overlap with our non-proliferation work.
- The Double Chooz Far detector has been filled, and commissioning data is pouring in - physics data-taking expected in March.

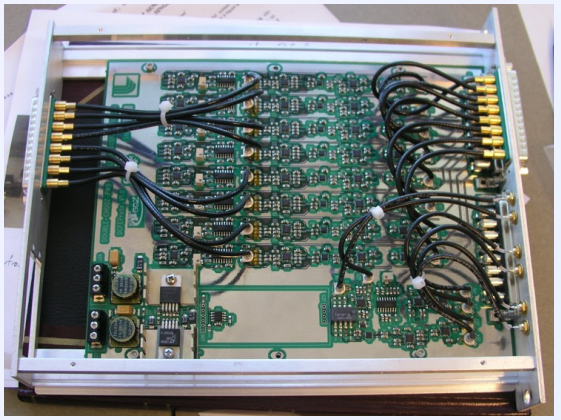




Major LLNL Contributions to Double Chooz



- Reactor Simulations and Antineutrino Flux predictions:
  - The sensitivity of the first physics results hinge largely on the precision of this prediction – this will remain true until, and to some extent even after, the near detector is completed.



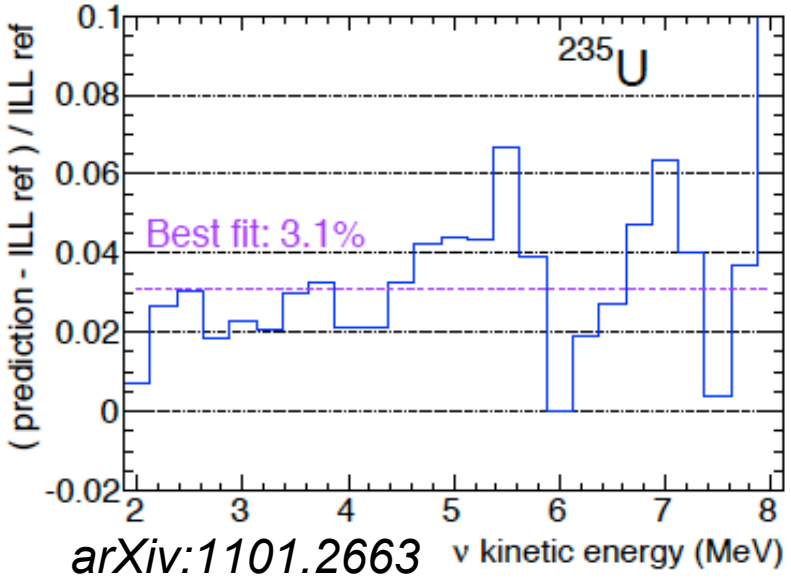
- Front-End Electronics
  - LLNL was asked to assist with this delayed critical path item. Within an intense 8 month period a single channel schematic was taken to a fully packaged 8-ch production ready module.
  - DOE-OS support received in FY09-10

- Calibration Systems
  - We will manage installation of the final far detector hardware item – the calibration glovebox, and provide and install it for the near detector

- Radiopurity
  - We have responsibility for maintaining the high levels of radiopurity required in the detectors, both by defining the acceptable limits and arranging and conducting radio-assays of detector components.

Recent result of French Double Chooz collaborators: "The Reactor Antineutrino Anomaly"

- Many improvements were made to the procedure for conversion of high-precision experimental electron spectra into antineutrino spectra:
  - Use of modern nuclear data, incorporating O(10^4) beta-branches
  - Better treatment of Coulomb and "Weak Magnetism" corrections
  - Off-equilibrium reactor effects
- Result: **previous spectrum is systematically low by ~3%**
- The world's expert on antineutrino spectra prediction has judged this approach to be credible:
  - the analysis approach is "...clearly better…",
  - "…the stated 3% shift looks reasonable…",
  - but it is not yet "… rigorously proven." (Petr Vogel, Private Communication)

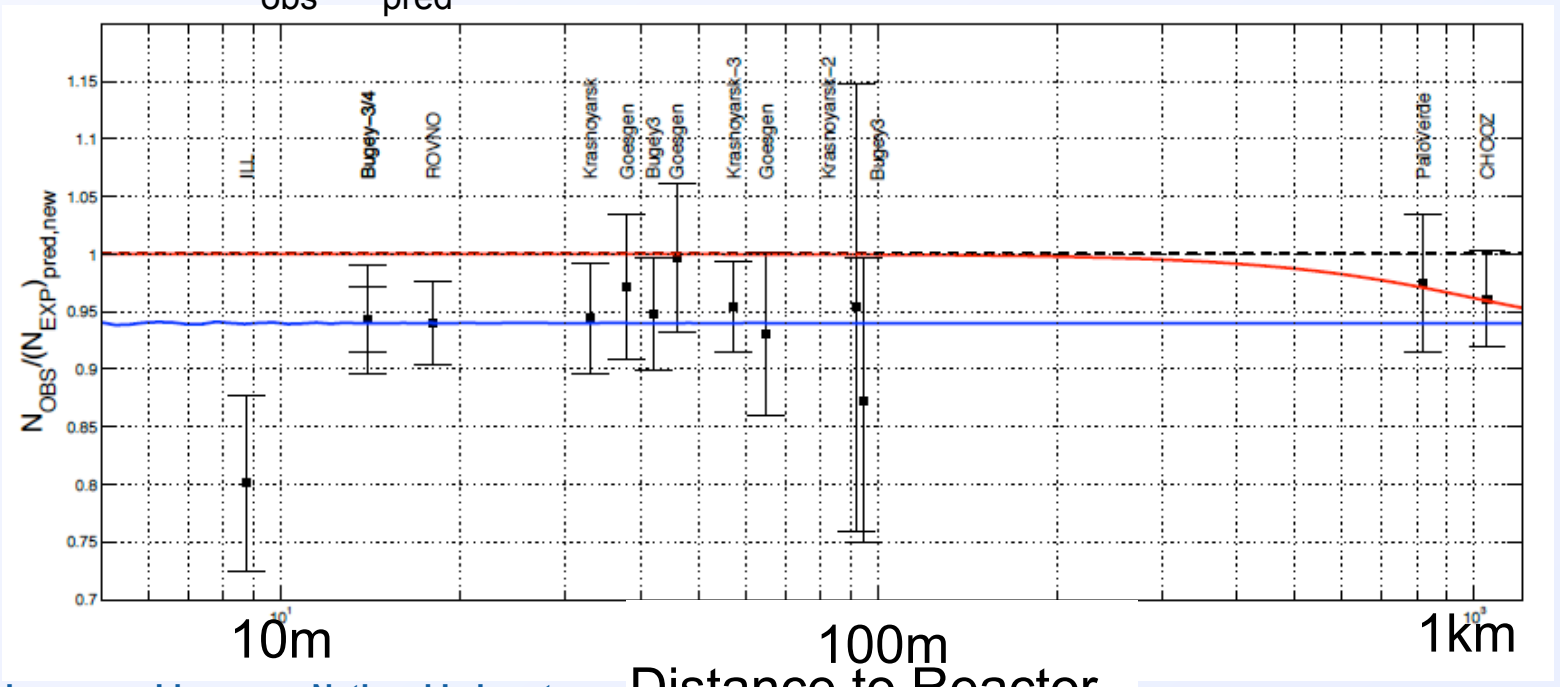


arXiv:1101.2663

Previous Short Baseline Reactor Experiments must be reanalyzed

- The flux prediction was a central ingredient of 12 previous oscillation experiments at baselines less than 100m
- Each had to be reanalyzed in light of this newly shifted prediction
- The result: new global "Reactor Antineutrino Anomaly" at 2 sigma significance:

$$N_{obs}/N_{pred} = 0.979 \pm 0.029 \Rightarrow 0.937 \pm 0.027$$



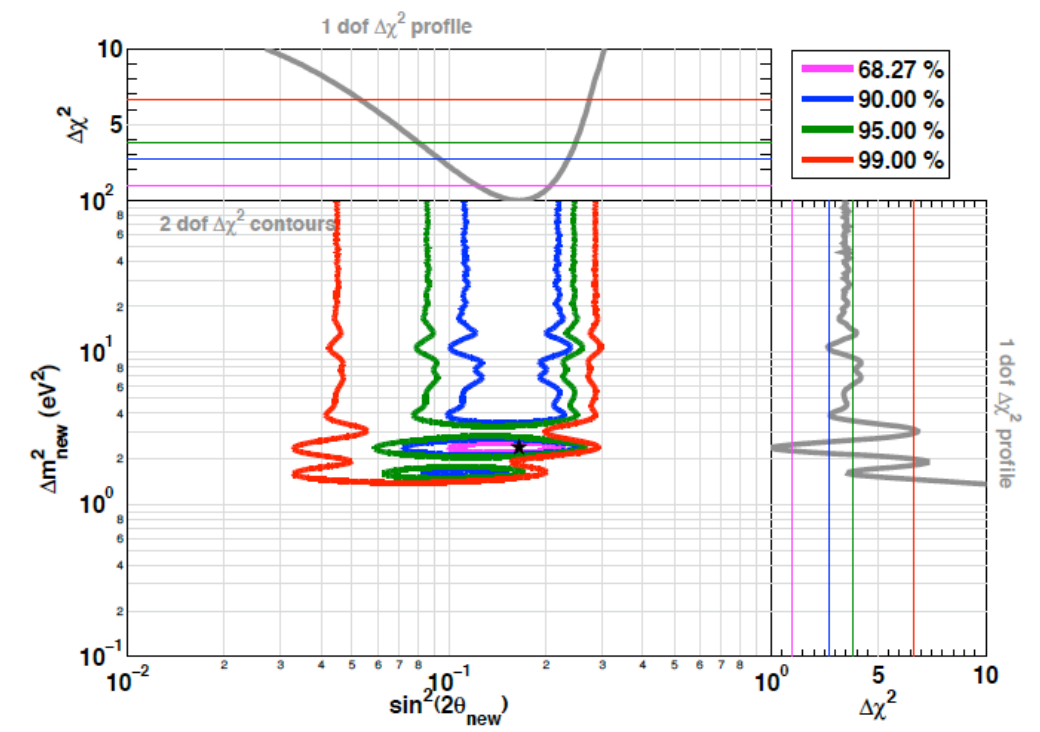
arXiv:1101.2755

Possible Explanations for the Anomaly

- A correlated systematic amongst the previous short baseline experiments
- A remaining systematic in the reactor flux prediction
- **Physics Beyond the Standard Model**,

  in the form of a

  sterile neutrino flavor
  - A combined re-analysis of **reactor**, **radiochemical** and **MiniBooNE** expts finds support for this hypothesis – **no oscillation disfavored at 99.93% C.L.**



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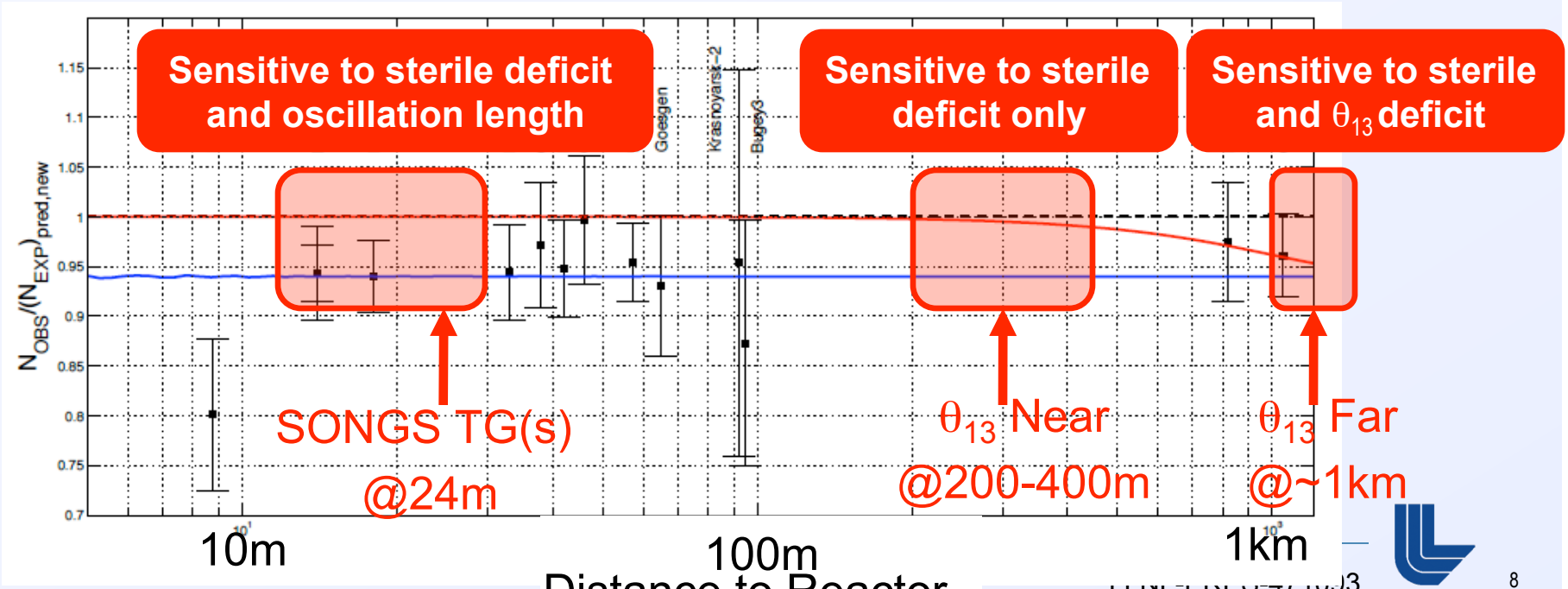
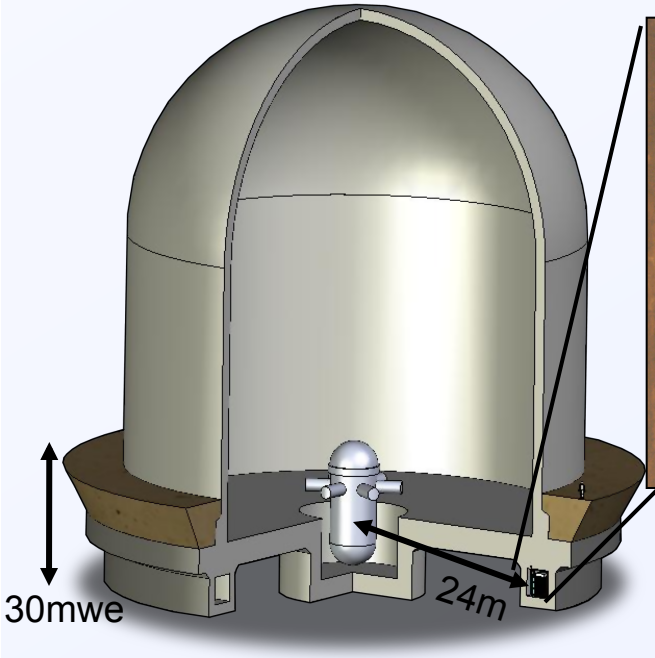
Only a new experiment @<100m could describe any new physics, and quickly resolve the reactor anomaly

- Only a short baseline (<100m) reactor experiment would have sensitivity to the sterile Δm^2 parameter, unlike θ_{13} Near detectors
- Due to high flux, could more quickly confirm accuracy of the spectrum prediction and existence of any anomaly, independent of all θ_{13} searches
  - Would, in fact, strengthen confidence in predictions used for θ_{13} expts.
- LLNL Group has access to the ideal site for such an effort, that is unique around the world: SONGS "tendon" galleries

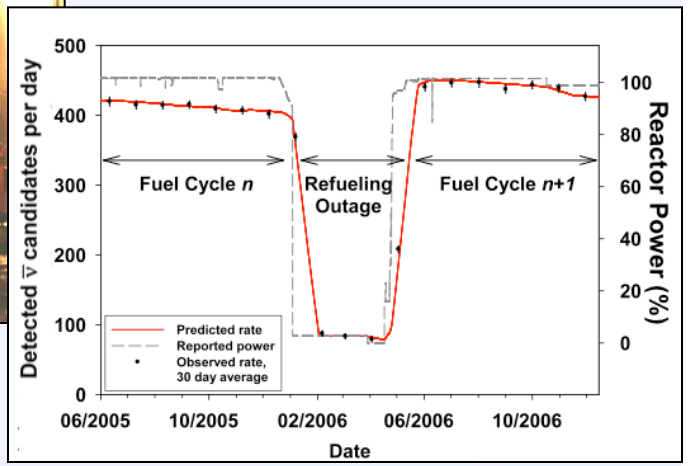


The San Onofre Nuclear Generating Station: Our laboratory for over a decade



SONGS1 antineutrino detector in the Unit2 Tendon Gallery

Direct Observation of reactor fuel burnup via antineutrino counting

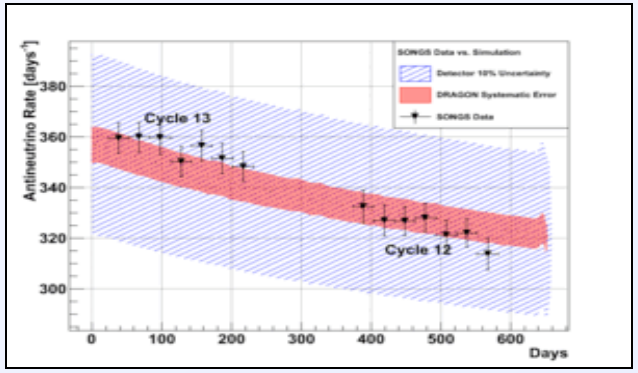


- We have cultivated an exceptionally strong and trusting relationship with SONGS:
  - A multitude of access requests have been readily granted since 1999
  - Provided with unescorted reactor access, deployment assistance, commercially sensitive fueling data, introductions to other operators, …..
- We possess unparalleled operational experience in this industrial environment:
  - **Five** antineutrino detector deployments since 2003

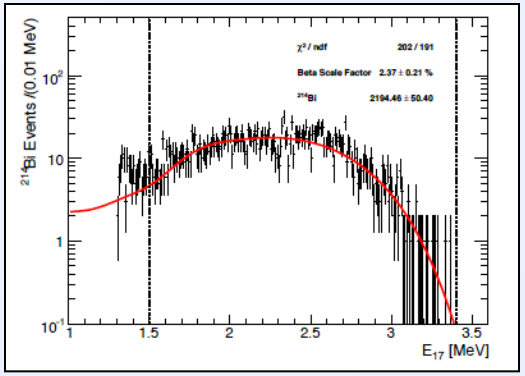
Our group has broad experience in neutrino physics, and working at SONGS

- Personnel:
  - 10+ cumulative years unescorted access at SONGS
  - Double Chooz members since 2005
  - Many years experience on KamLAND, SuperK, T2K, EXO, etc

- Expertise:
  - Design and deployment of multiple antineutrino detectors, aside from those mentioned above
  - Extensive simulation capabilities, both for detector design and reactor simulation
  - Beta-decay analysis code – could be used for independent cross-check of new spectrum prediction



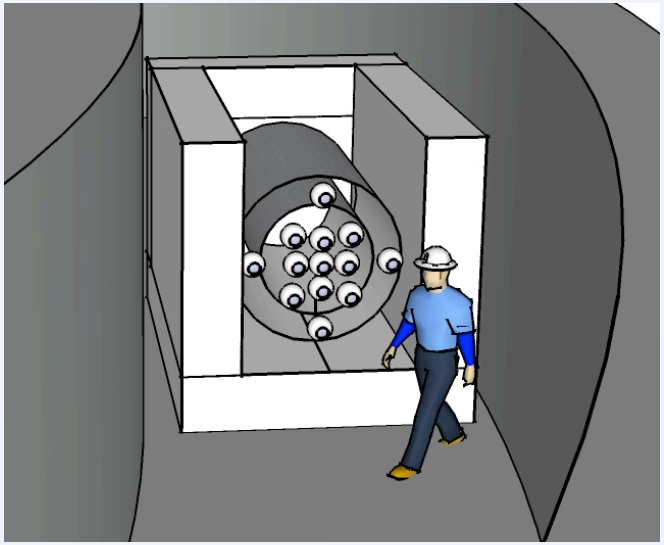
Reactor Simulation compared to SONGS1 data

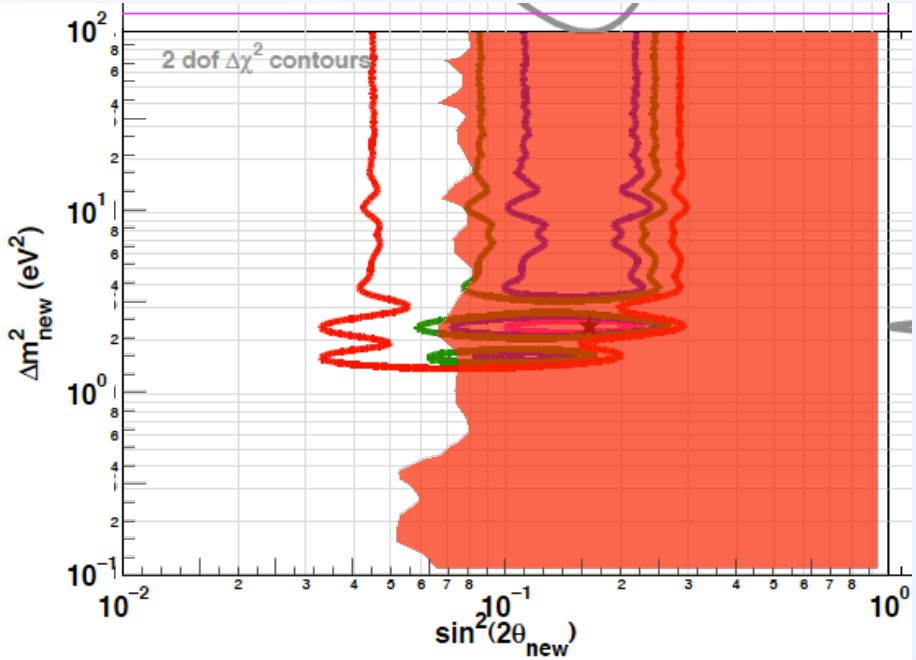


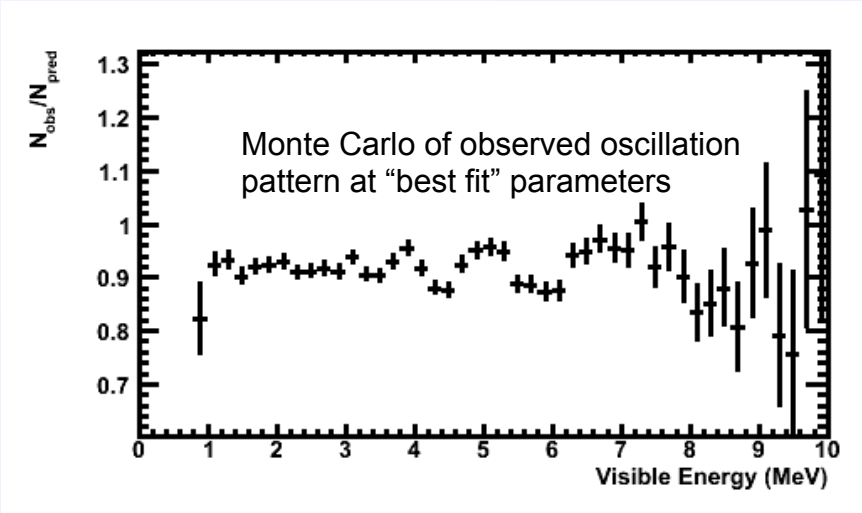
Fit to ^{214}Bi data including 212 decay modes

The Southern California Reactor Antineutrino Anomaly Monitor (SCRAAM) would have excellent sensitivity

- Preliminary studies of a modest 1-2 ton detector (1000+ $\bar{\nu}$/day) operating for ~200 days indicate:
  - Could exclude ~95% of allowed $\sin^2(2\theta)$ phase space
  - 3σ discovery potential for value of Δm^2 less than ~5 eV^2 – only accessible at reactors via O(10m) baseline measurement

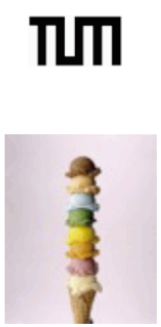






We propose to form a collaboration to fully develop the SCRAAM concept

- Potential collaborators, with whom we already work, include
  - UC Davis (Svoboda)
  - Kansas State (Horton-Smith)
  - Univ. of Alabama (Piepke, Busenitz, Stancu)
  - Stanford (Gratta)
  - MIT (Conrad)….
- SCRAAM could be operational very rapidly (2012) due to:
  - Our access to a unique location with favorable baseline, flux, and overburden
  - Extensive detector design experience, both in-house and amongst our collaborators
- Although there is currently no other effort dedicated to short baseline physics, the recent papers are stirring a lot of interest:



Workshop on Sterile Neutrinos and on the Reactor (anti)-Neutrino Anomaly

T.U.M, 8th of February 2011