

Potential Impact of New Measurements and Applied Neutrino Physics Goals

December 11, 2012

Nathaniel Bowden



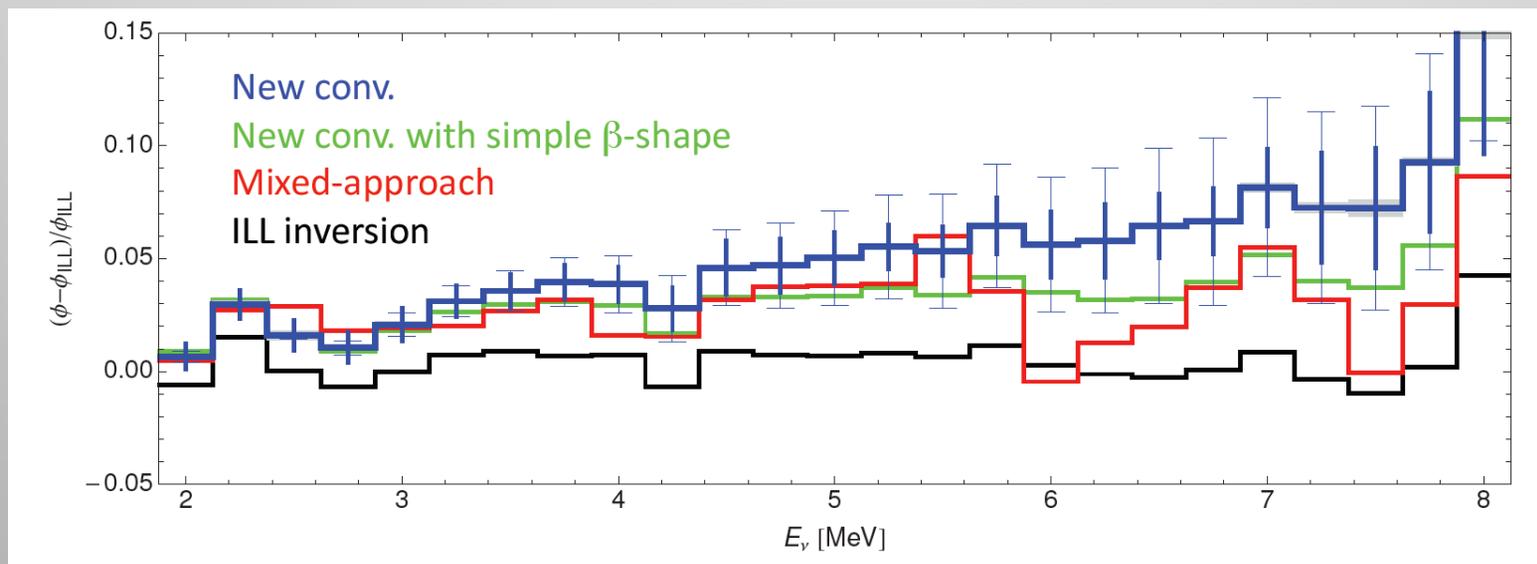
LLNL-PRES-607582

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC



Recent Re-evaluations of the Reactor Antineutrino Flux

- There have been several efforts to improve predictions of the reactor antineutrino flux
- All predictions based on conversion of reference beta electron spectra measured at ILL research reactor: ~3% increase in flux
- Two largely independent predictions agree:

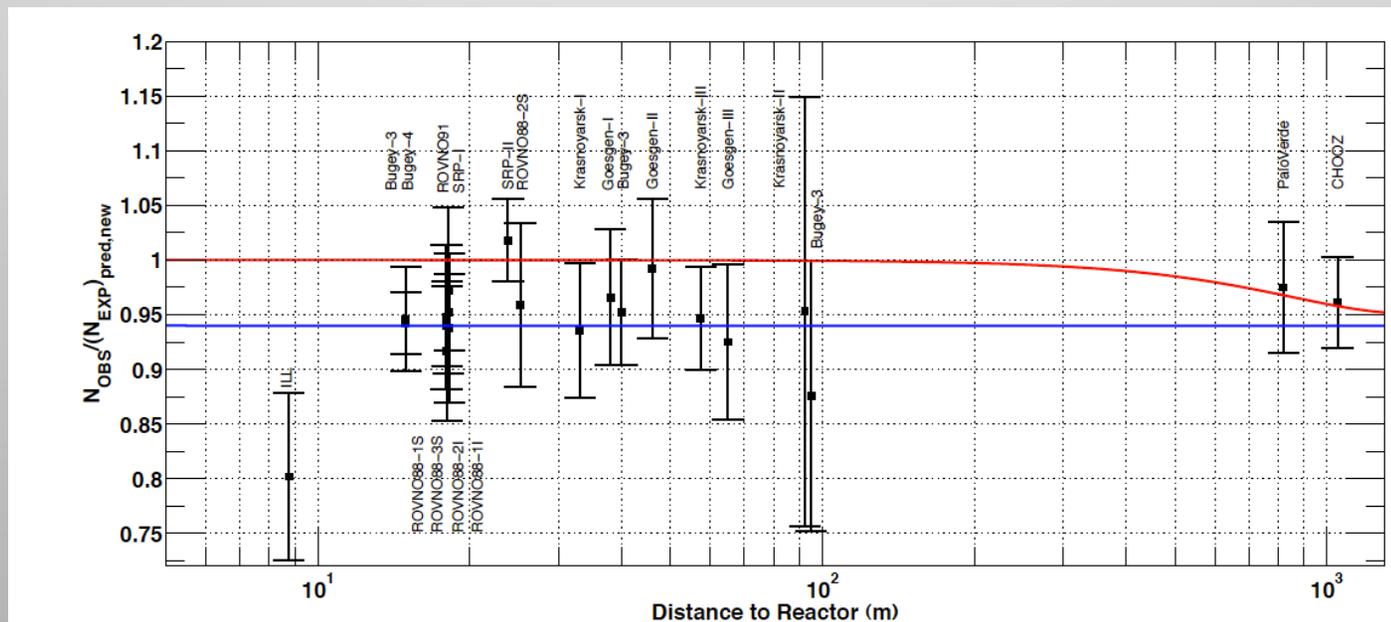


Mueller, et al: arXiv:1101.2663
Huber: arXiv:1106.0687

The Reactor Antineutrino Anomaly

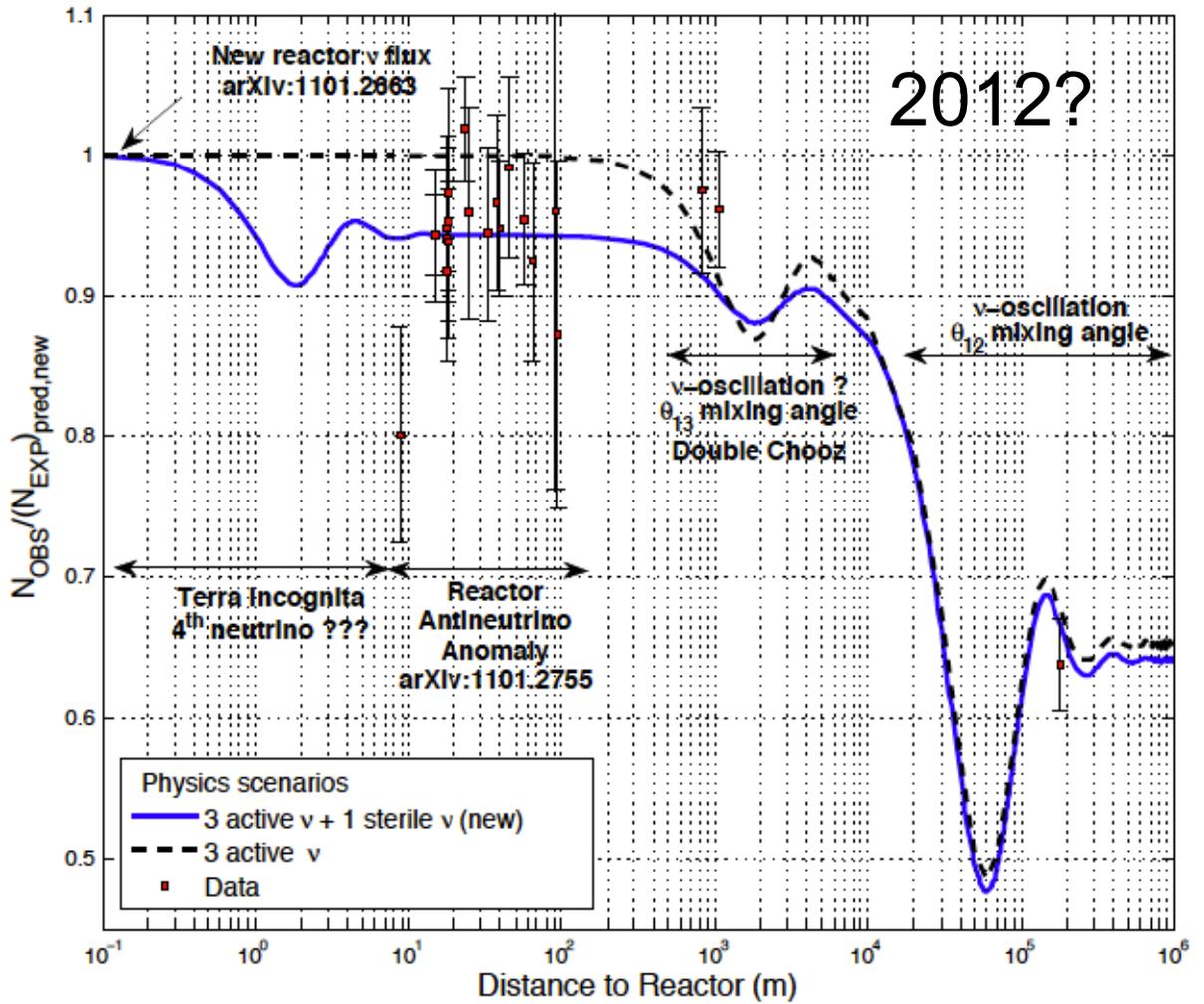
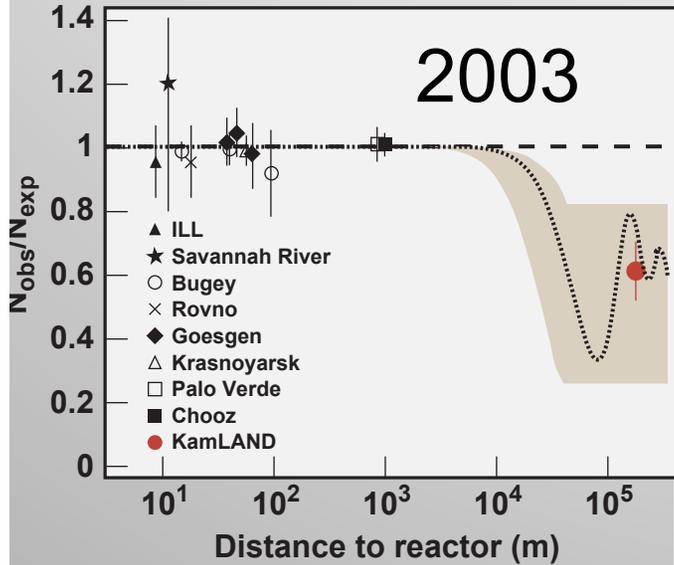
- The many previous short baseline reactor experiments have been reanalyzed, in light of the new antineutrino flux prediction
- The result: new global “Reactor Antineutrino Anomaly”

$$N_{\text{obs}}/N_{\text{pred}} = 0.979 \pm 0.029 \Rightarrow 0.943 \pm 0.023$$

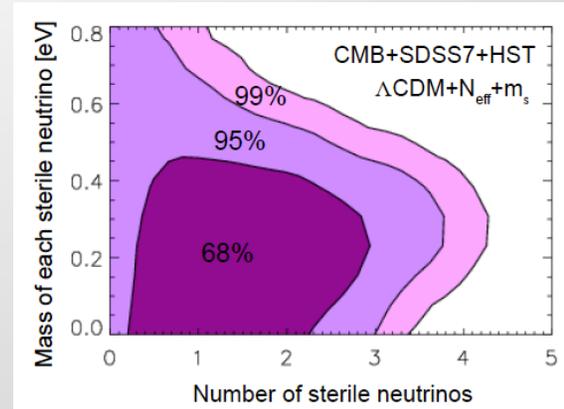
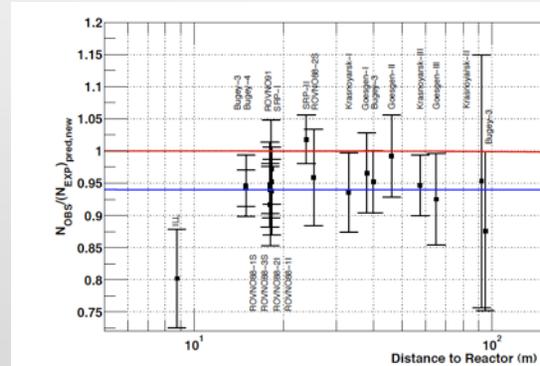
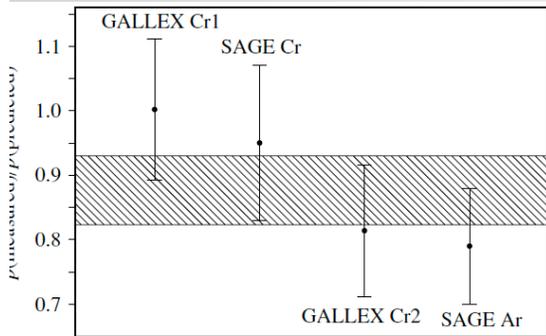


arXiv:1101.2755v4

One interpretation of the Reactor Anomaly: a short baseline oscillation to a fourth “sterile” neutrino



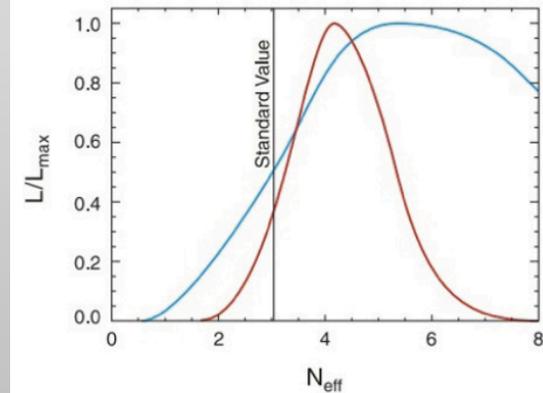
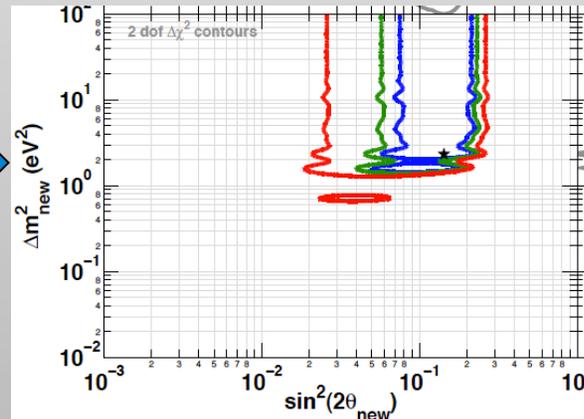
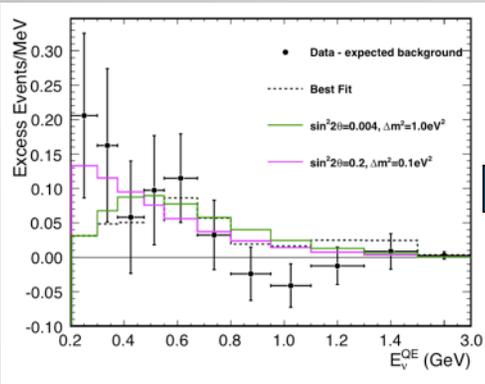
The Reactor Anomaly is consistent with other hints of sterile flavor(s)



SAGE/GALLEX

Reactor Anomaly

Cosmology WMAP 7-year



MiniBOONE

Combined

Astrophysical measurements also consistent with additional flavour(s) at $\sim\text{eV}$ scale

Strong interest in definitive resolution to this question

Short-Baseline Neutrino Workshop

12-14 May 2011

STERILE NEUTRINOS AT THE CROSSROADS
September 25-28, 2011 • Blacksburg, VA • USA

Future Short-Baseline Neutrino Experiments at Fermilab: Needs and Options

Fermilab WH1W
March 21, 2012

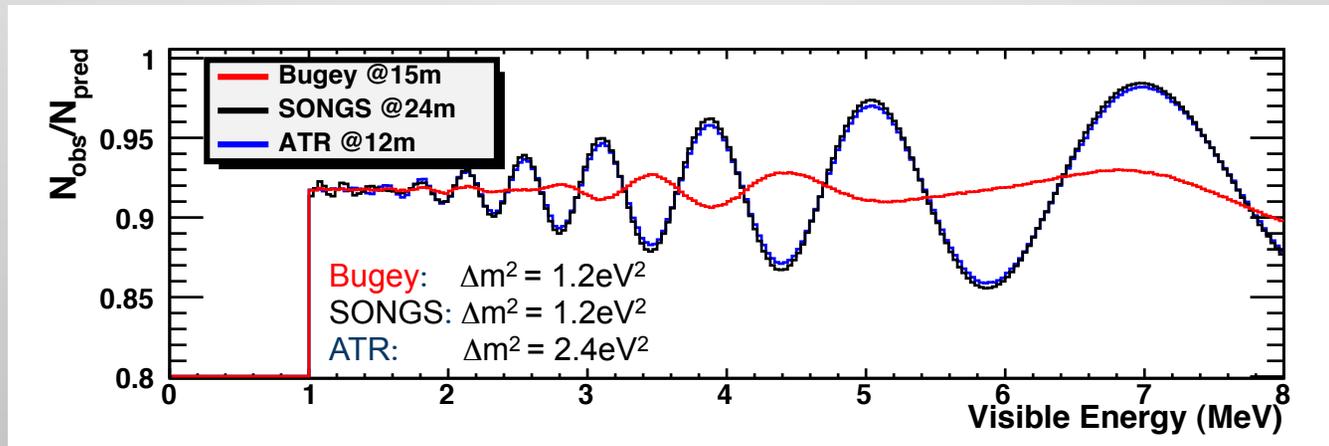
Light Sterile Neutrinos: A White Paper

K. N. Abazajian^{a,1} M. A. Acero,² S. K. Agarwalla,³ A. A. Aguilar-Arevalo,² C. H. Albright,^{4,5} S. Antusch,⁶ C. A. Argüelles,⁷ A. B. Balantekin,⁸ G. Barenboim^{a,3} V. Barger,⁸ P. Bernardini,⁹

- Most anomalies or hints take the form of a deficit or excess relative to expectation
 - Unresolved systematics in predictions and/or measurements?
- Strong desire in community for definitive experiments based on measurement of oscillation pattern in different systems

Motivation for a New Short Baseline Reactor Experiment

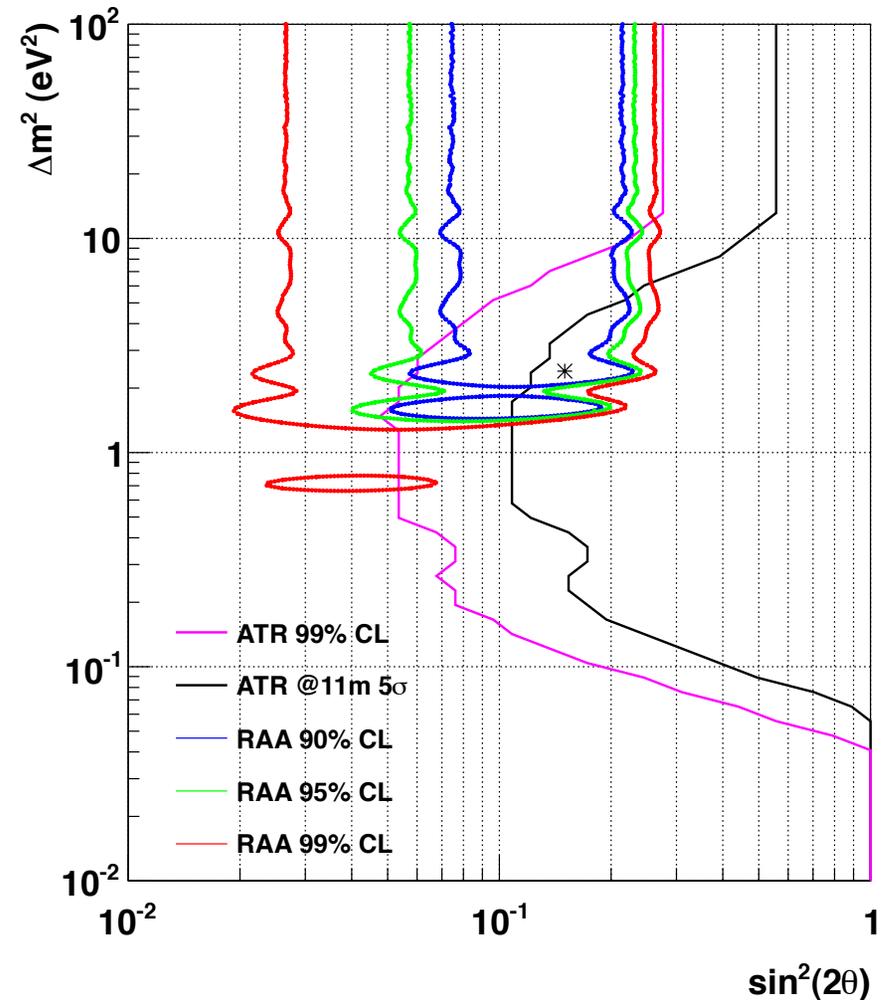
- Multi-MeV span of reactor spectrum and multi-baseline detector provide probe of oscillatory behavior with $\Delta m^2 \sim \text{eV}^2$
 - No previous SBL reactor experiment optimized in this respect



- Due to the large reactor antineutrino flux, a new short baseline experiment could provide input to the anomaly question relatively quickly and at relatively low cost

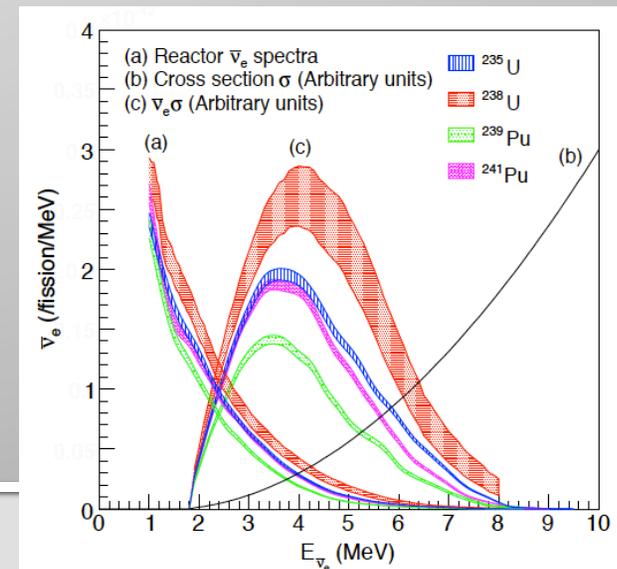
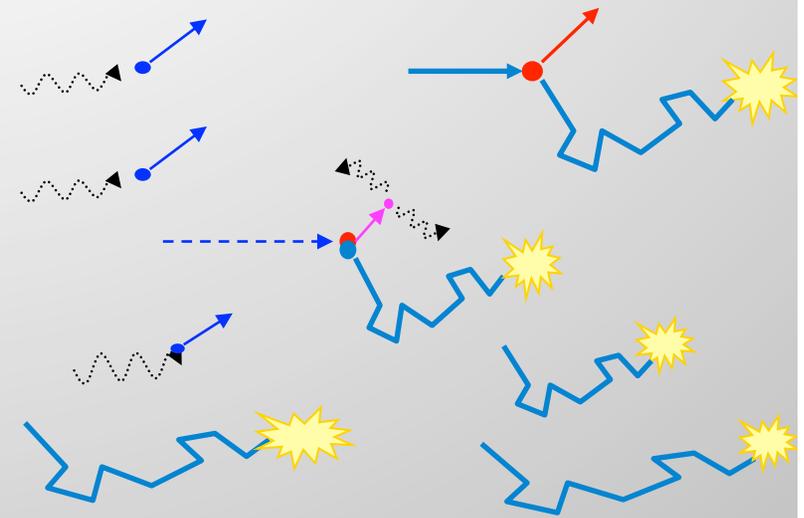
Optimized Reactor Measurement can address favored RRA Phase Space

- An experiment sited close to a compact core can probe anomaly phase space $<10\text{eV}^2$, including best fit point.

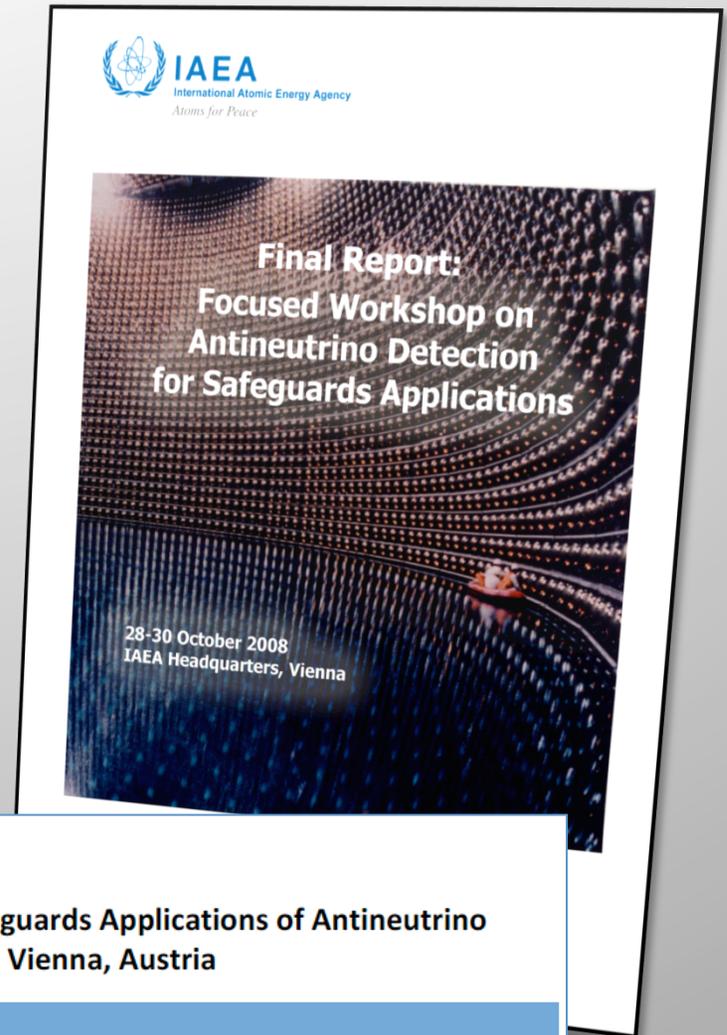
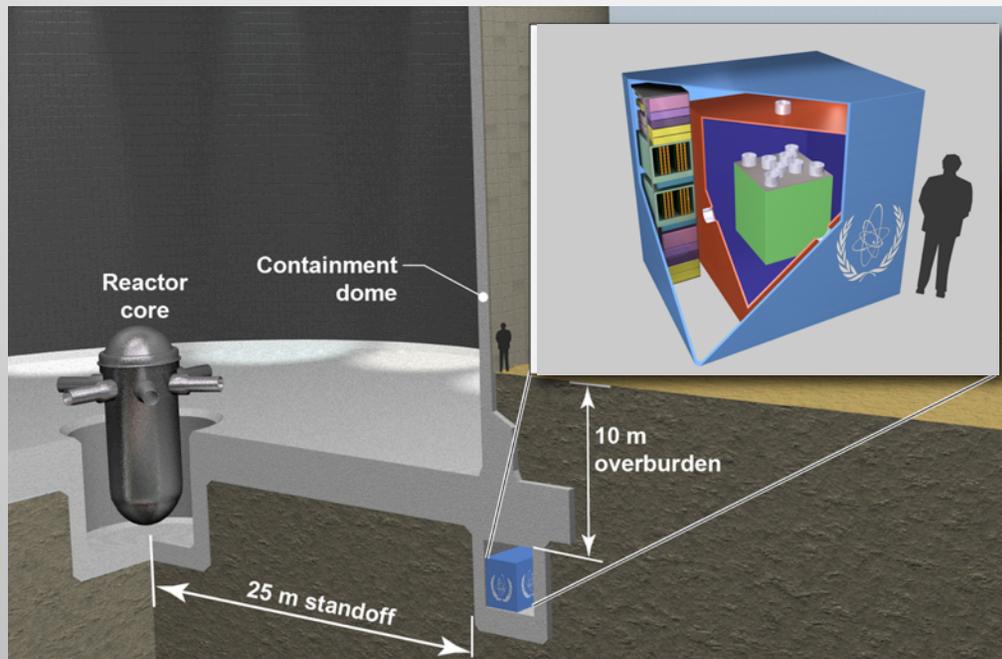


Key Difficulties for a Short Baseline Reactor Measurement

- Unrecoverable spread in baseline due to finite size of reactor core and detector position resolution
- High Background due to:
 - Shallow overburden
 - Reactor correlated gammas and neutrons
 - Compact detector size → limited shielding
- Uncertainty in reactor antineutrino energy spectrum
 - Knowledge of spectral shapes for ^{235}U , ^{239}Pu , ^{238}U , ^{241}Pu
 - Knowledge of fuel composition



There is increasing interest in (Short Baseline) Antineutrino Monitoring of Reactors



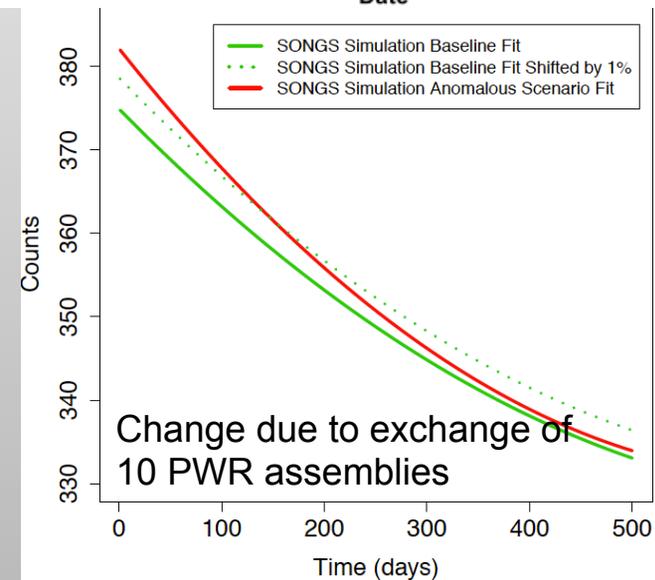
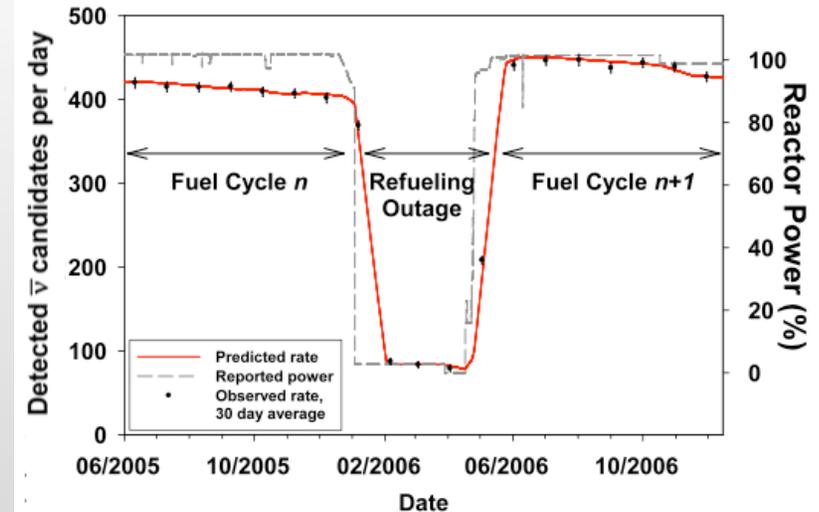
AGENDA

Ad Hoc Working Group on Safeguards Applications of Antineutrino Detectors, 14 September 2011, Vienna, Austria

Reactor Monitoring Demonstrations

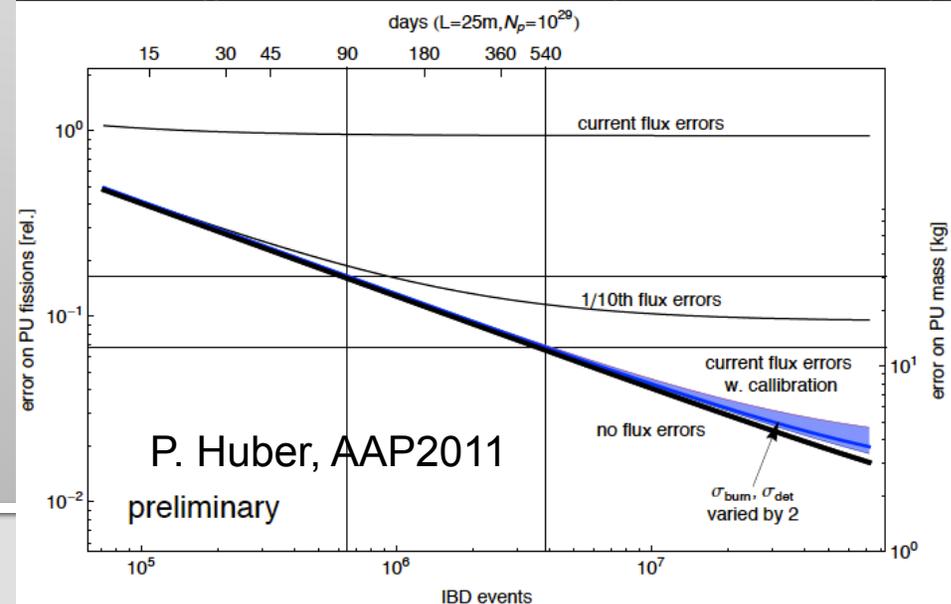
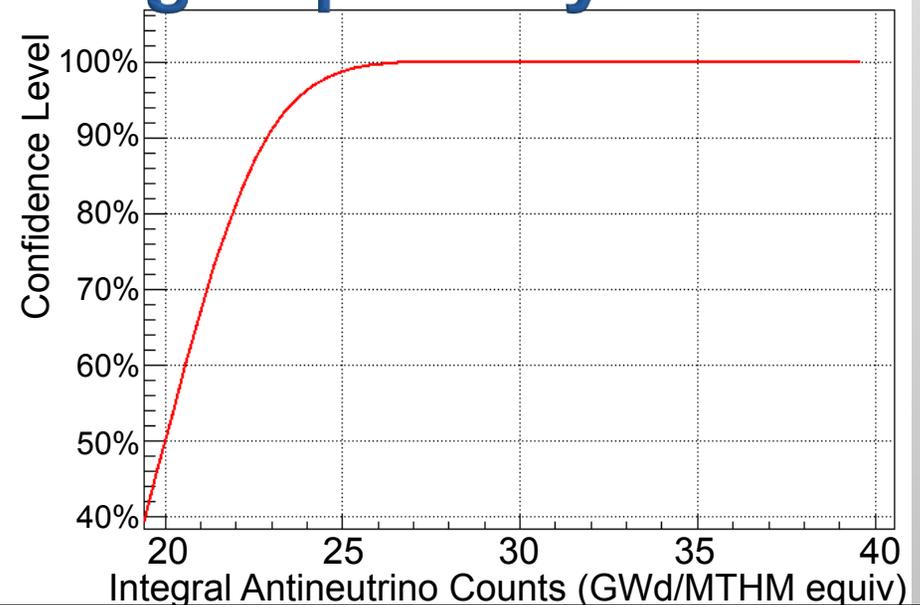
- Relative rate measurements provide verification of:
 - Operational history
 - Relative Power History
 - Fuel loading through burnup effect

- Sensitivity to diversion/replacement somewhat limited:
 - Effect on slope of burnup curve is small
 - Could be masked by overall power shift



Absolute Flux and Spectral Measurements would improve monitoring capability

- Absolute power and/or inventory measurement required for some applications, e.g. verification of Pu disposition
- Spectral measurements could break degeneracy between power and fuel composition



Conclusions

- A new short baseline reactor experiment has the potential to provide timely input on the reactor antineutrino anomaly, as well as high precision spectral measurements
- Such an experiment will be challenging due to the high background rates at shallow overburden and near reactor
- Site selection will have to balance background, physics sensitivity, accessibility, ...
- A new Short Baseline experiment would benefit the emerging applied antineutrino physics field:
 - Reduce anomaly allowed phase space
 - Provide benchmark spectral measurement of single well-understood core
 - Improve technology for high background environment