PROSPECT - A Precision Reactor Neutrino Oscillation and Spectrum Experiment

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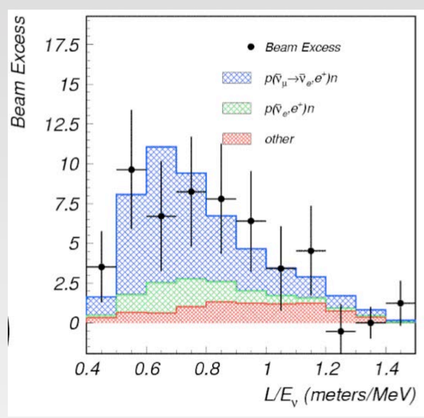
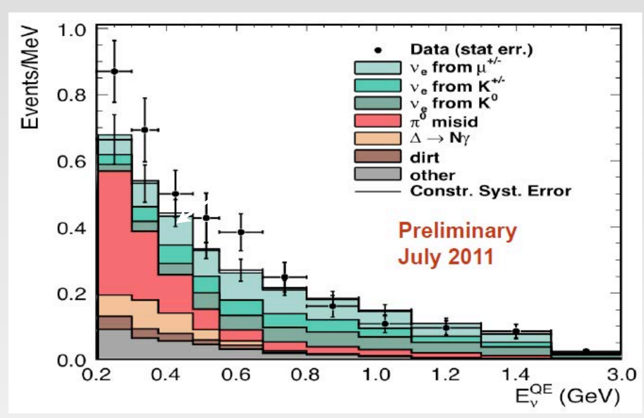
Neutrino Anomalies & Sterile ν Hypothesis

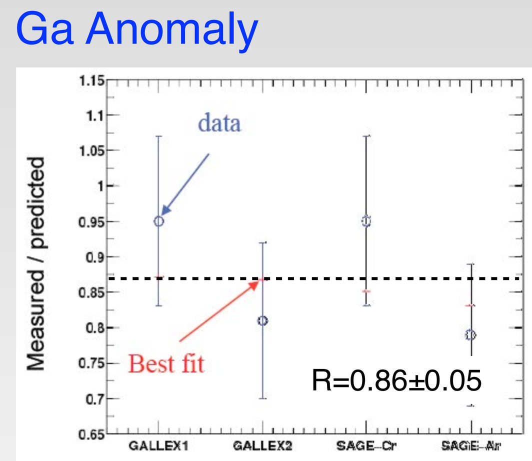
LSND



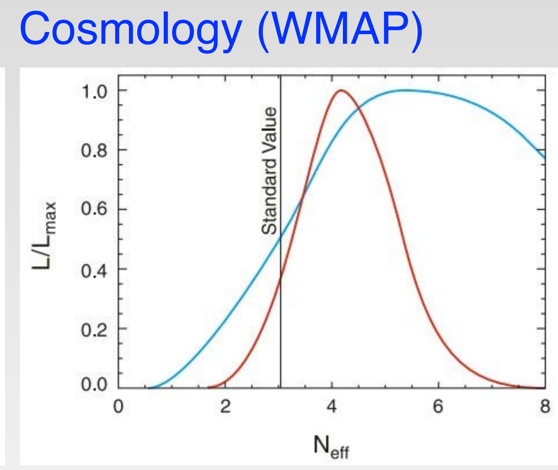
MiniBoone



Ga Anomaly



Cosmology (WMAP)



Anomalies in Neutrino Data

LSND ($\bar{\nu}_e$ appearance)
MiniBoone (ν_e appearance)
Ga calibration source anomaly
N_{eff} in cosmology
Short-baseline reactor anomaly ($\bar{\nu}_e$ disappearance)

If new oscillation signal,
implies $\Delta m^2 \sim O(1 eV^2)$ and $\sin^2 2\theta > 10^{-3}$
➔ very short baseline oscillation for reactor ν

Systematics or experimental effects?
➔ test each experimental effect.

$$L_{osc} = 2.5 \frac{E(MeV)}{\Delta m^2 (eV^2)} \simeq 2 - 10\ m$$

"Light sterile neutrinos: A white paper", arXiv:1204.5379

Reactor Flux Measurements

Preliminary

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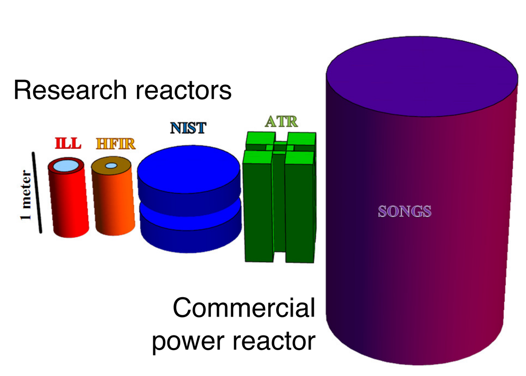
Ref: Daya Bay, Neutrino 2014

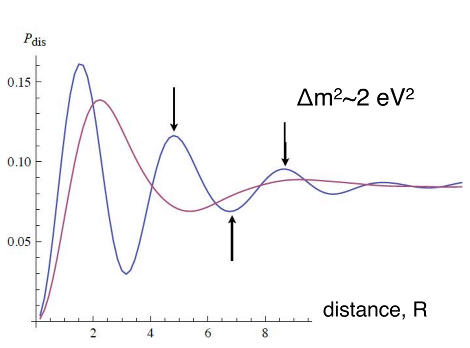
A Short-Baseline Reactor Experiment

Compact Reactor Core as Source

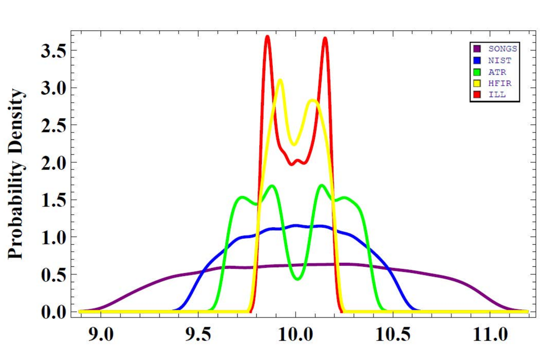
Reactor Core Size



Neutrino Oscillations



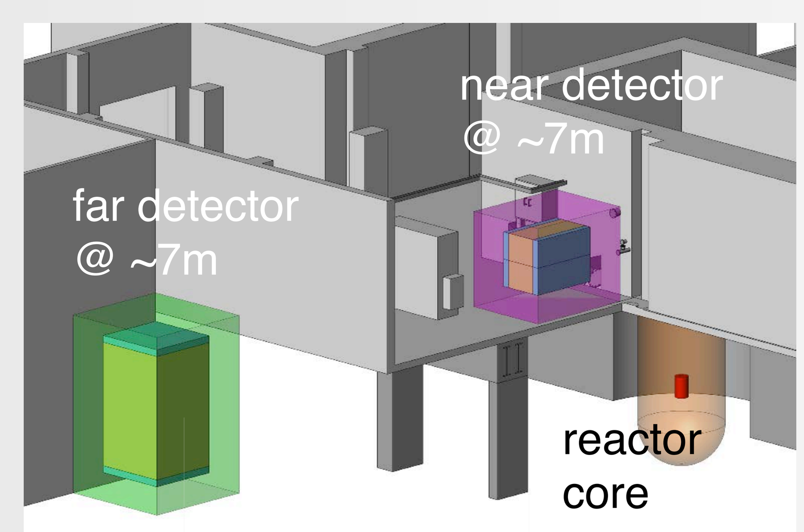
Pathlength Spread from Core Size
assume point detector at 10m



Research reactors have compact cores with diameters <1m

Small reactor core preferred to avoid washing out short-baseline oscillation effect

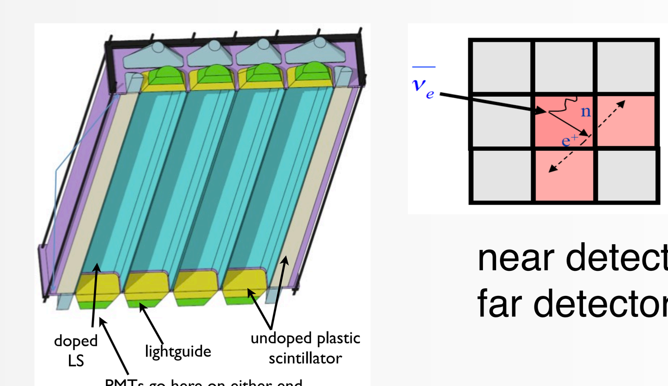
1 Reactor + 2 Detectors



Configuration: 2 detectors at ~7-20m baselines

Reactor: HFIR at ORNL as default location, 85 MW_{th}, 41% duty cycle, compact core, reactor-off periods allow study of backgrounds

Detector Concept

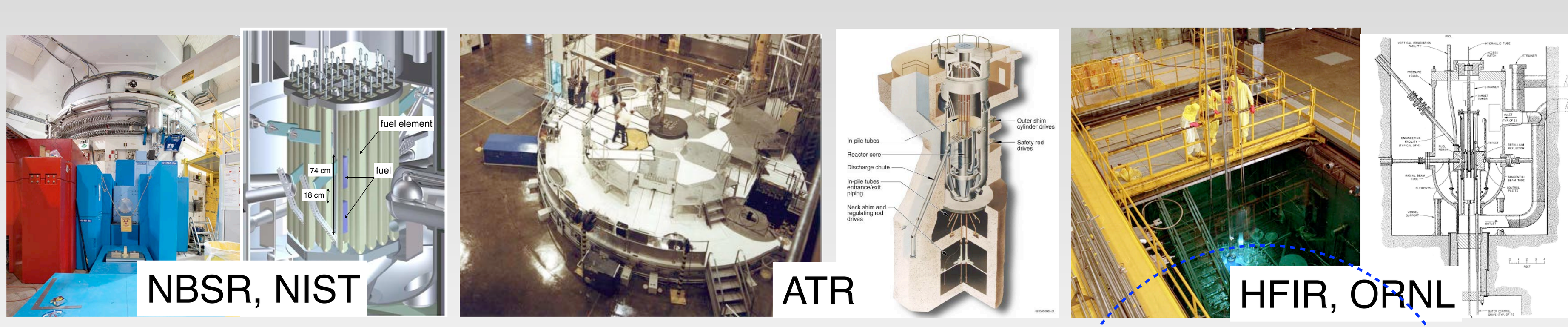


near detector ~2 tons target
far detector: ~ 10 ton target

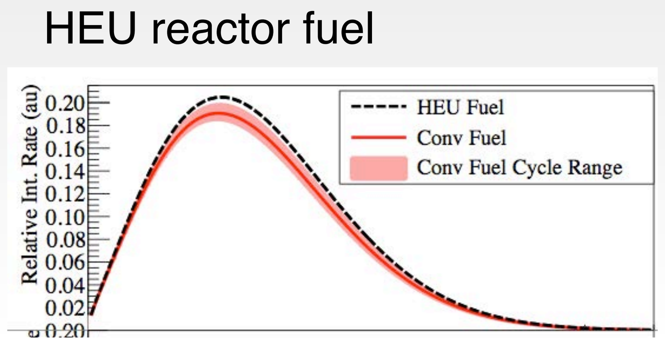
Segmented Detector - position resolution for oscillation search, background rejection via topology, low inactive mass and uniform response for good energy resolution

Target Materials
^{6}Li liquid scintillator – localized neutron capture, capture and neutron recoil ID possible
Gd liquid scintillator – proven technology, neutron recoil ID possible via PSD

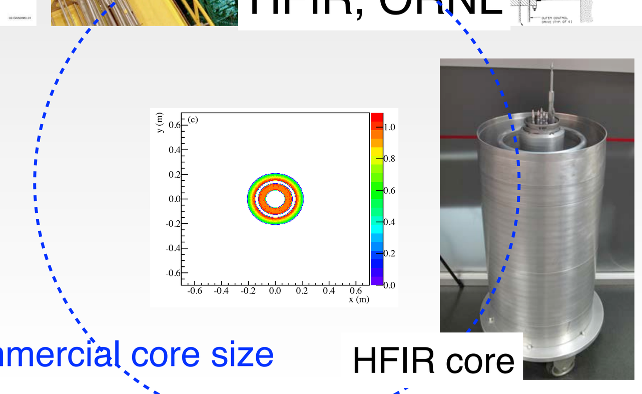
US Research Reactors



HEU reactor fuel

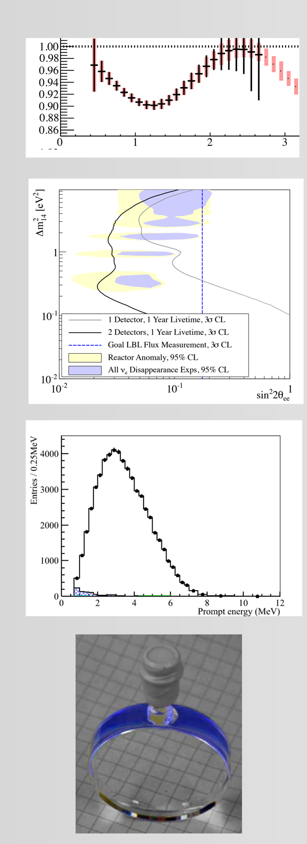


Research Reactors: approximate a point source of neutrinos, run with HEU fuel



Very short baseline (L~10m) measurements offer opportunities for precision studies of the reactor spectra, fuel evolution and searches for new physics.

Scientific Opportunities



Primary Physics Objectives
Definitive short-baseline oscillation search with high sensitivity.

Test of the oscillation region suggested by reactor anomaly and $\bar{\nu}_e$ disappearance channel (3 years of run time can exclude virtually all the implied oscillation region at 5σ).

Precision measurement of reactor $\bar{\nu}_e$ spectrum for physics and safeguards.

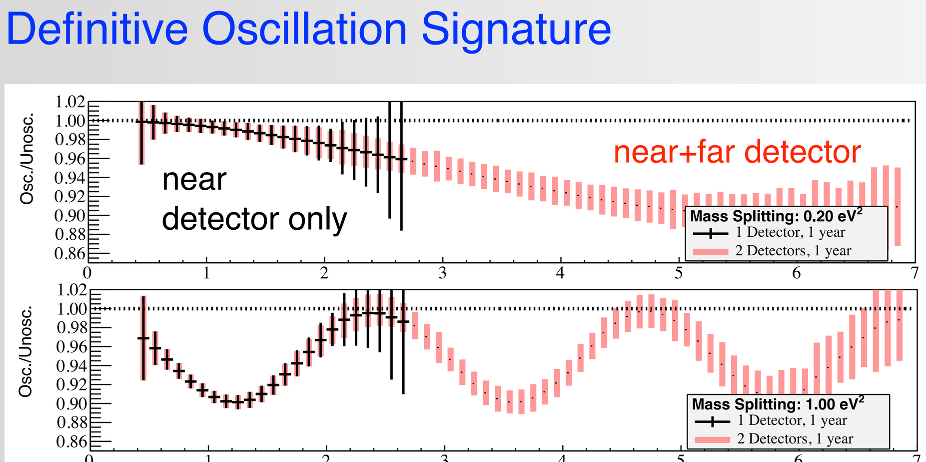
Secondary Physics and Applied Goals
^{6}Li doped scintillator development.

Segmented antineutrino detectors for near-surface operation; develop antineutrino-based reactor monitoring technology for safeguards.

Possible first measurement of antineutrinos from spent fuel.

Sensitivity and Scientific Reach

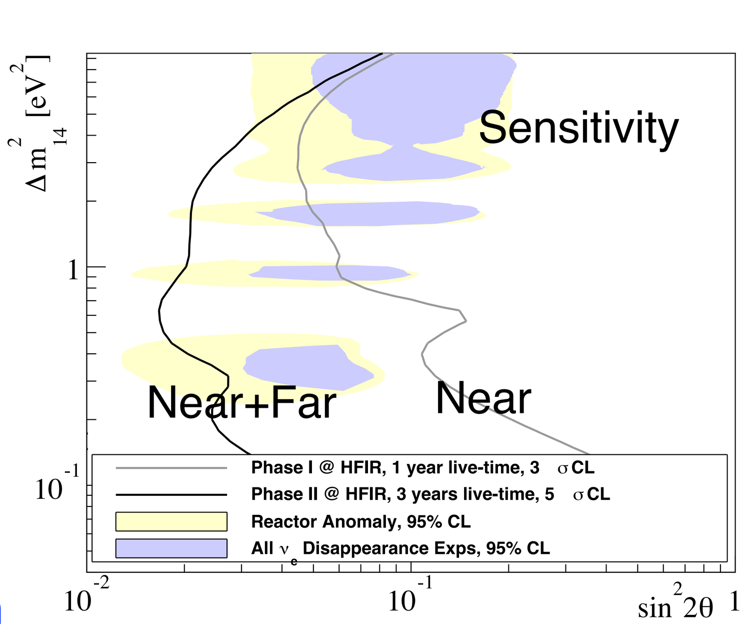
Definitive Oscillation Signature



Map out oscillation as a function of energy
- determine event energy

Map out oscillation as a function of distance
- move detector
- event position reconstruction
- extended, segmented detector

Closer baselines probe higher mass-squared splittings. Wider baseline range allows for a better oscillation signature with baseline.



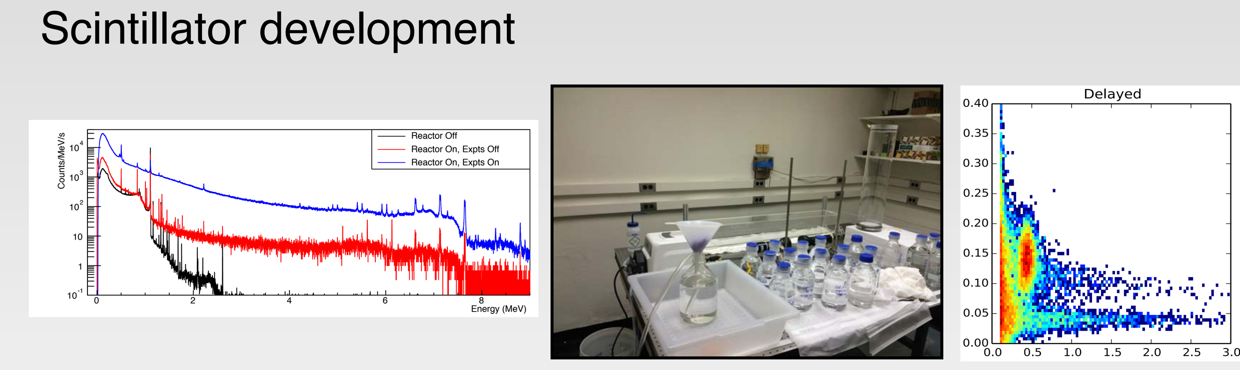
Phased Approach

Near detector:	3σ in 1 year
Near + far detectors:	5σ in 3 years

Physics Goals
Search for sterile $\bar{\nu}_e$ oscillations at short-baseline.
Probe and resolve "reactor anomaly".
Precision measurement of reactor $\bar{\nu}_e$ spectrum for physics and safeguards.

PROSPECT R&D

Background characterization and logistics studies at reactor
Detector and shielding design+prototyping
Scintillator development



see posters by N. Bowden and T. Langford

Technically Driven Schedule
2014: R&D with test detectors close to reactor core.
2015: Measurement of spectrum with near detector.
2016: Test of favored oscillation region at 3σ.
2016-18: Definitive experiment (5σ) with near+far detectors.
3 year run time excludes virtually all oscillation region at 5σ

PROSPECT white paper: arXiv:1309.7647

Images and figures: Courtesy of ORNL, NIST, INL, Daya Bay, and PROSPECT

June 2014