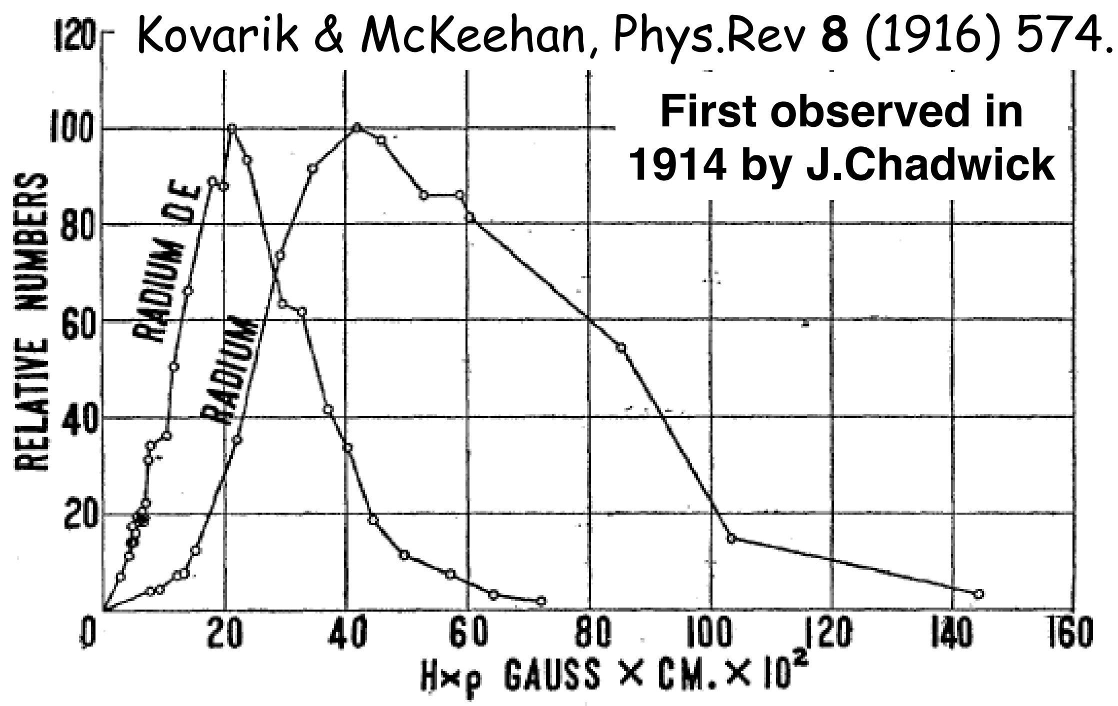
PROSPECT: The Precision Reactor Oscillation and Spectrum Experiment

David E. Jaffe
April 18, 2016

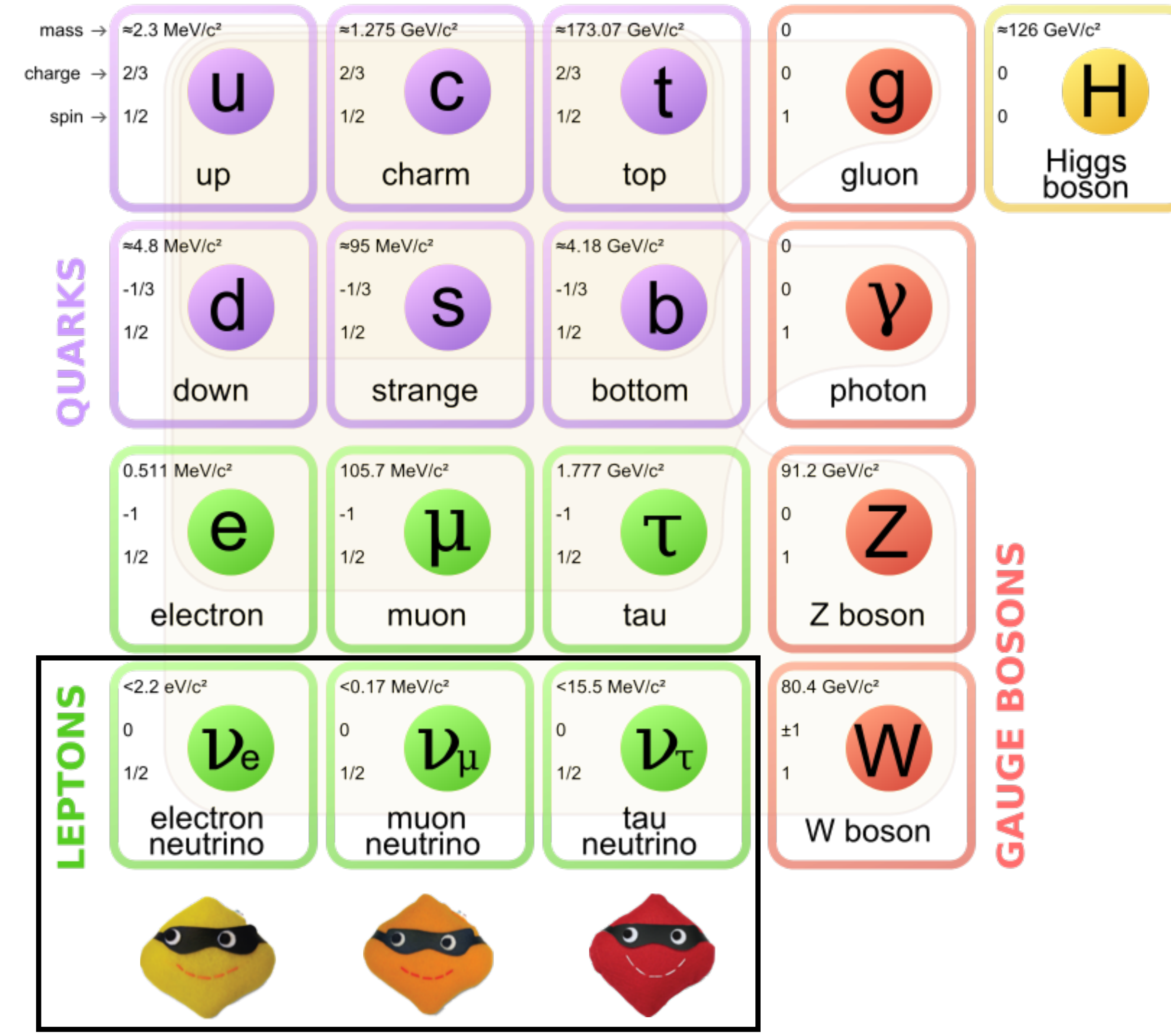
Many thanks to PROSPECT collaborators, especially Tom Langford (Yale) and Bryce Littlejohn (IIT), for their slides.

Neutrinos in the Standard Model



Energy of electron

Pauli(1930): "I have hit upon a desperate remedy to save…the law of conservation of energy."



20 July 1956, Volume 124, Number 3212 **SCIENCE**

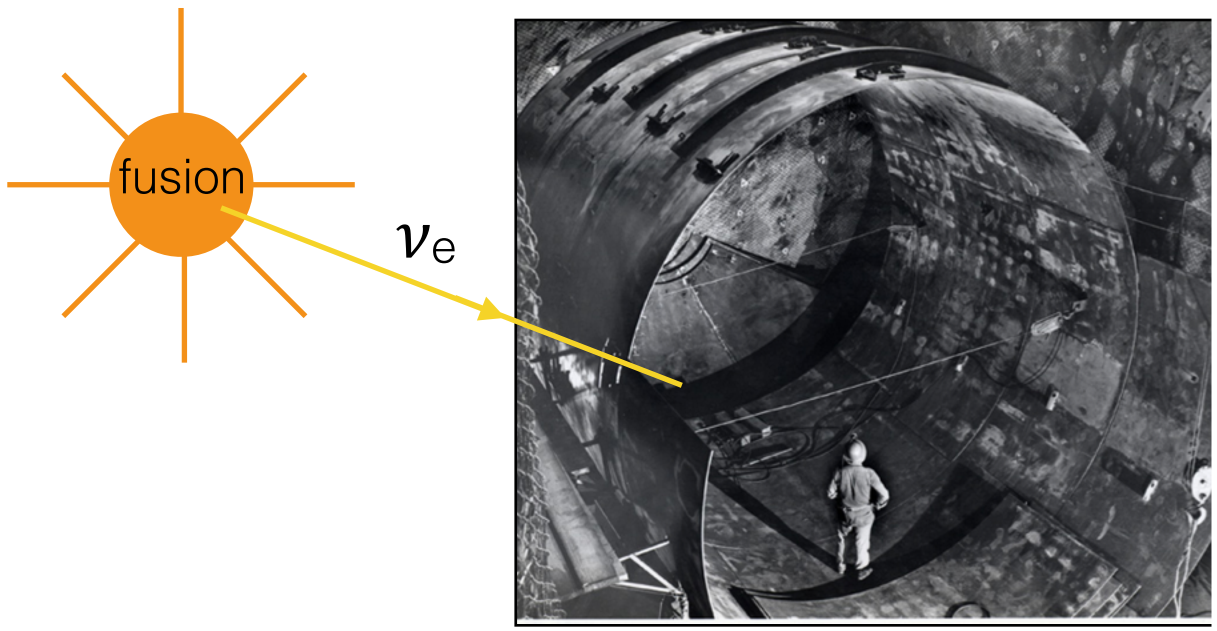
Detection of the Free Neutrino: a Confirmation

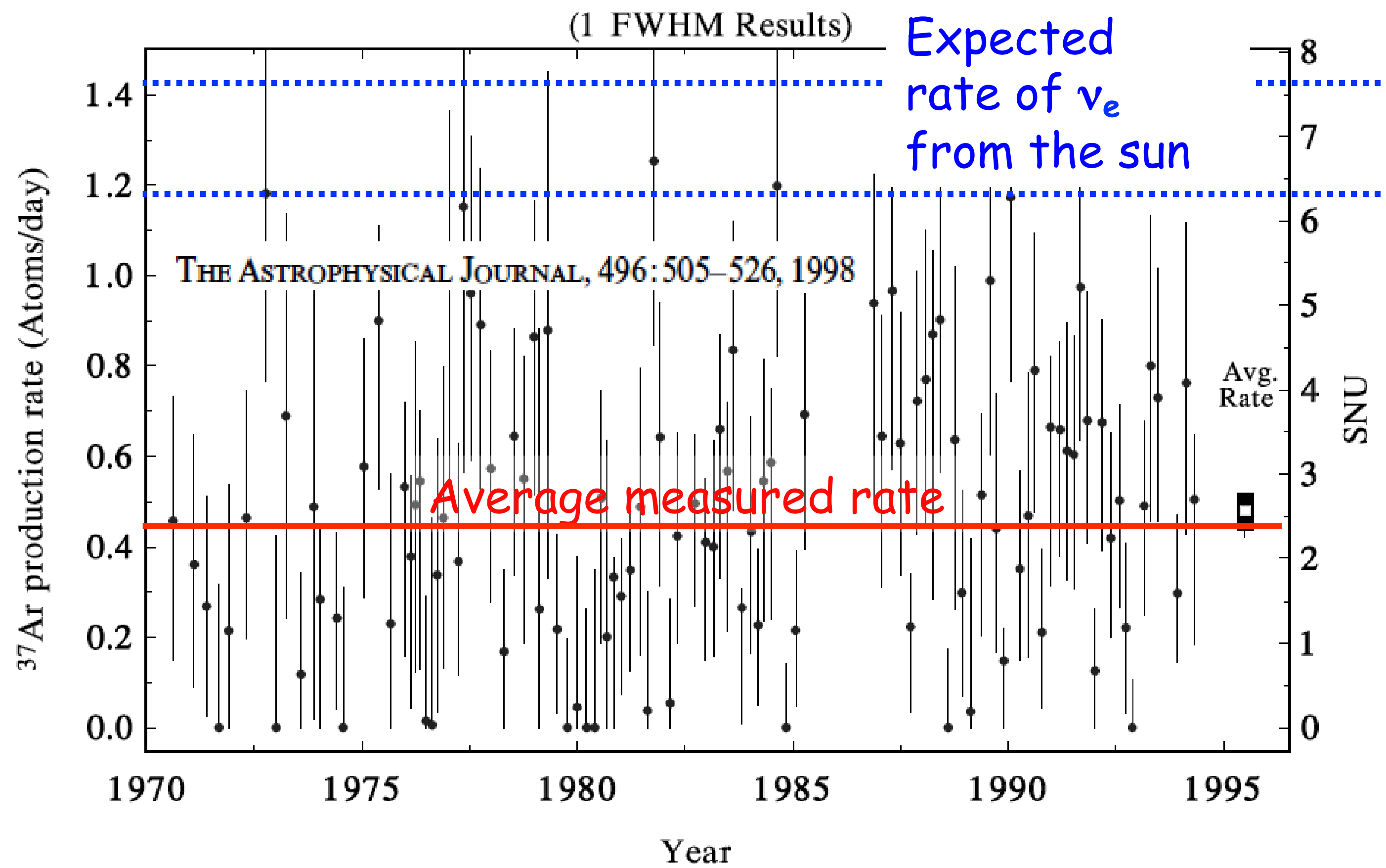
C. L. Cowan, Jr., F. Reines, F. B. Harrison, H. W. Kruse, A. D. McGuire

- Neutrinos were added to the SM to address the beta-decay "anomaly"
- *Successfully detected ~40 years later at the Savannah River Reactor*

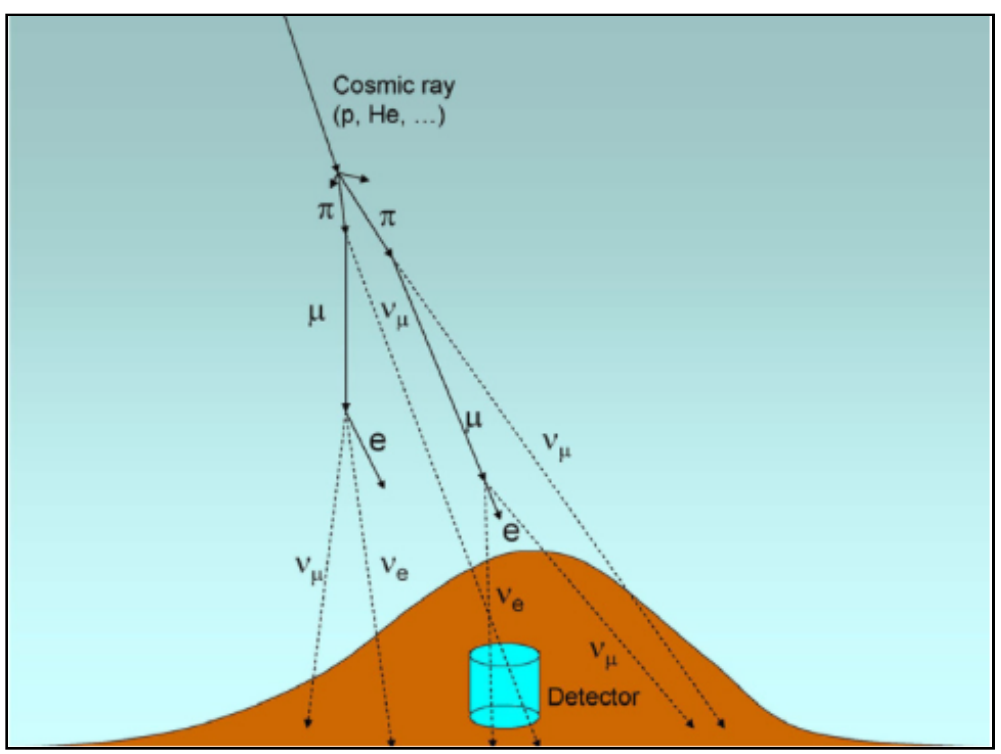
Neutrino Anomalies…

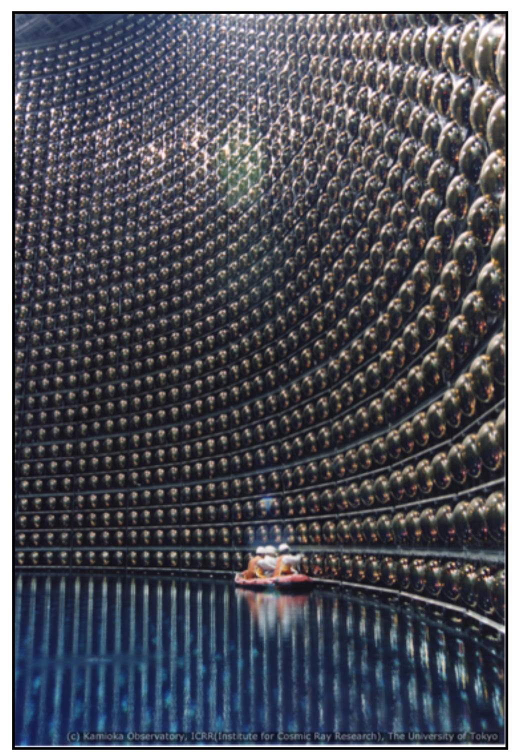
solar neutrino anomaly

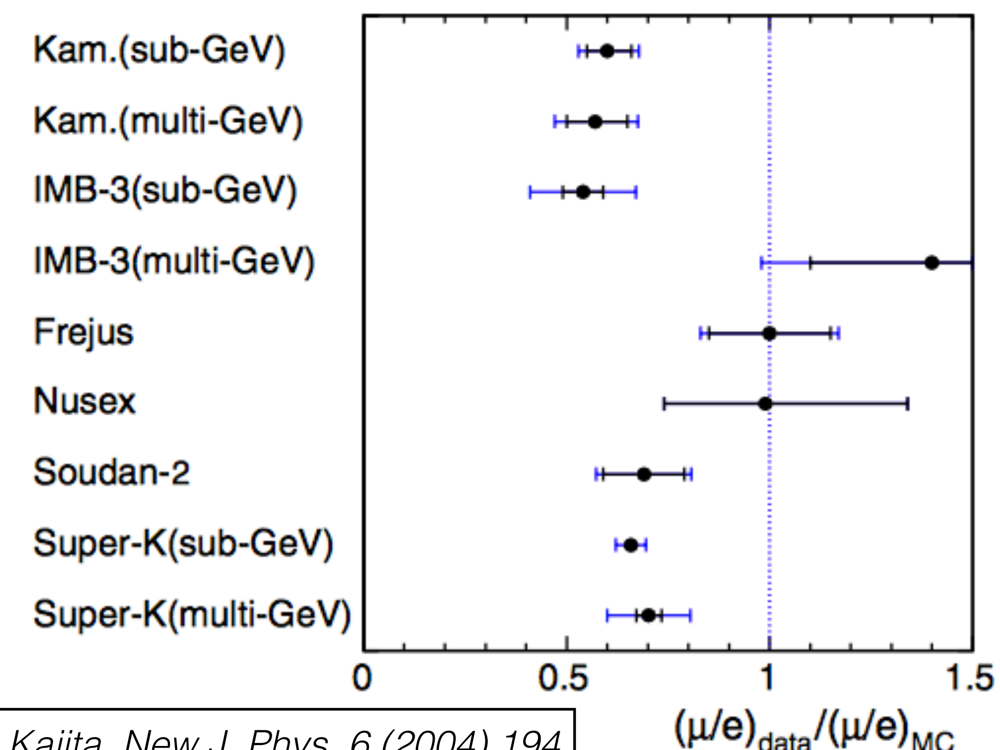




atmospheric neutrino anomaly



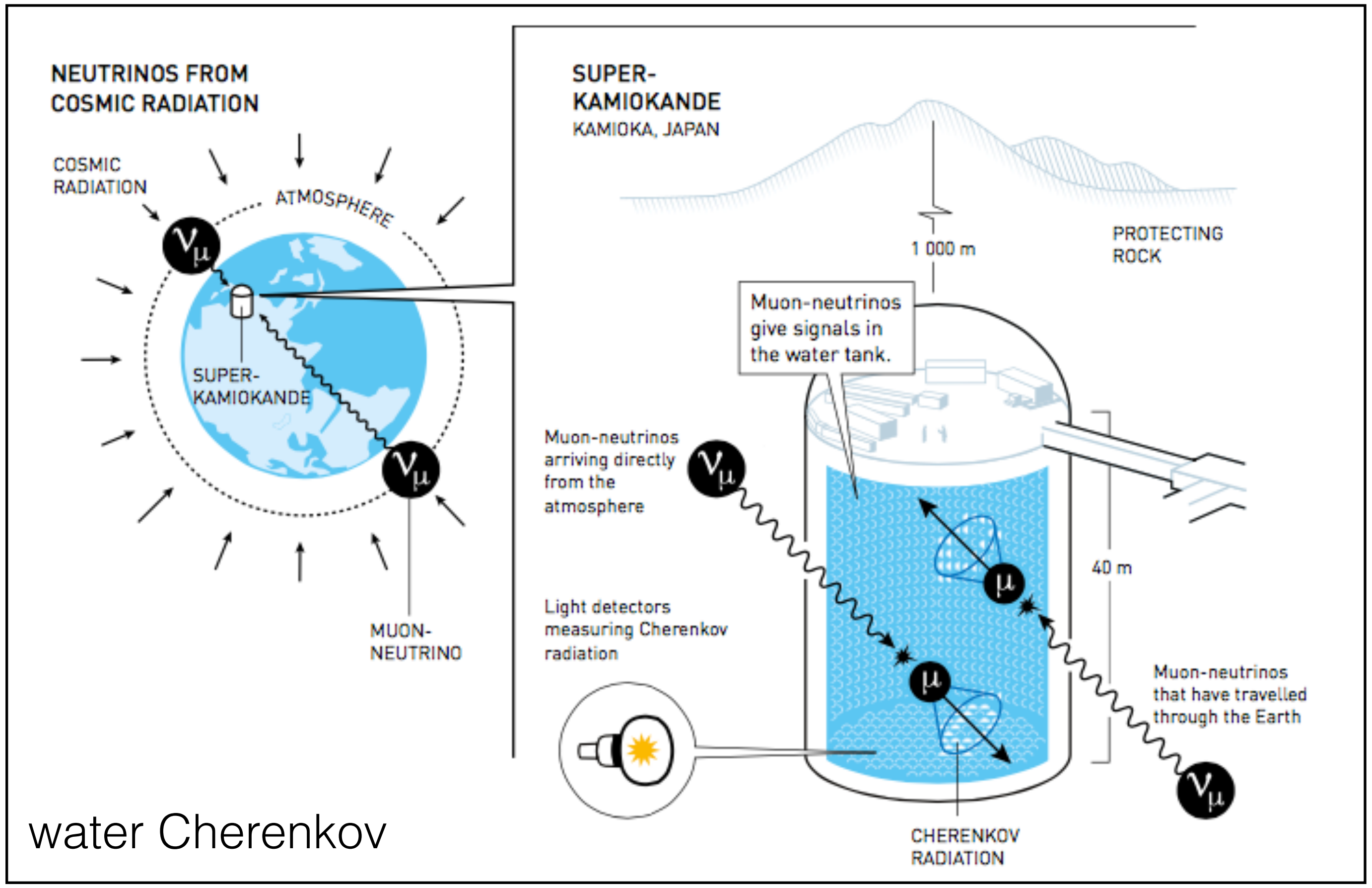




T. Kajita, New J. Phys. 6 (2004) 194

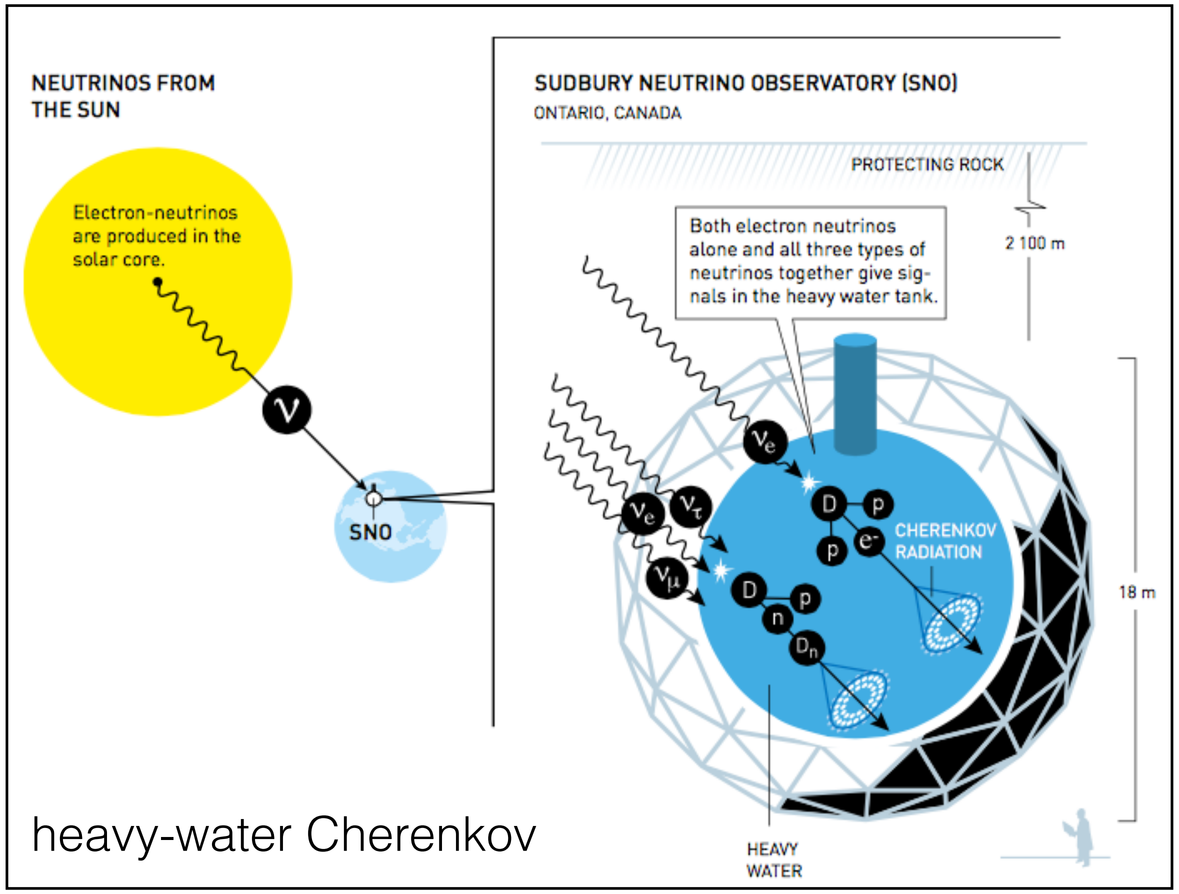
… Lead to Discoveries

Super-Kamiokande 1998: solved atmospheric anomaly



water Cherenkov

SNO 2001: solved solar anomaly



heavy-water Cherenkov

$\nu_\mu \rightarrow \nu_\tau$ oscillation through the earth

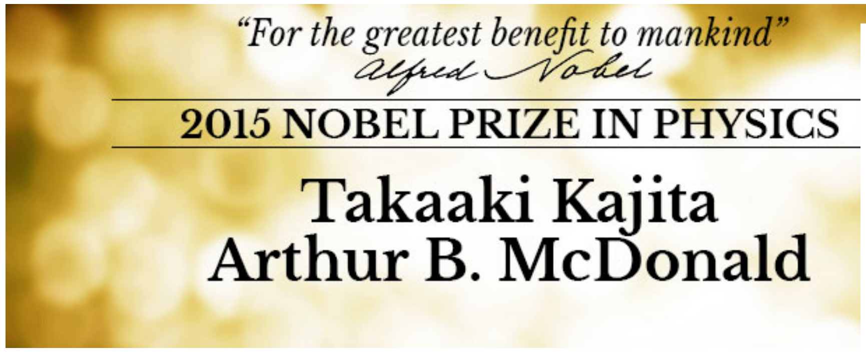
sum of all ν matched solar prediction

The Nobel Prize in Physics 2002

Raymond Davis Jr., Masatoshi Koshiba,

Riccardo Giacconi

"for pioneering contributions to astrophysics, in particular for the detection of cosmic neutrinos"



"for the discovery of neutrino oscillations which shows that neutrinos have mass"

Neutrino Oscillations

Neutrinos undergo oscillations between flavor and mass states, implying they are massive (although very light) particles.

flavor states *mass states*

$$\begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix} = U \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$$

$$where\ U = \begin{pmatrix} U_{e1} & U_{e2} & U_{e3} \\ U_{\nu 1} & U_{\nu 2} & U_{\nu 3} \\ U_{\tau 1} & U_{\tau 2} & U_{\tau 3} \end{pmatrix}$$

production *propagate* *PMNS mixing matrix*

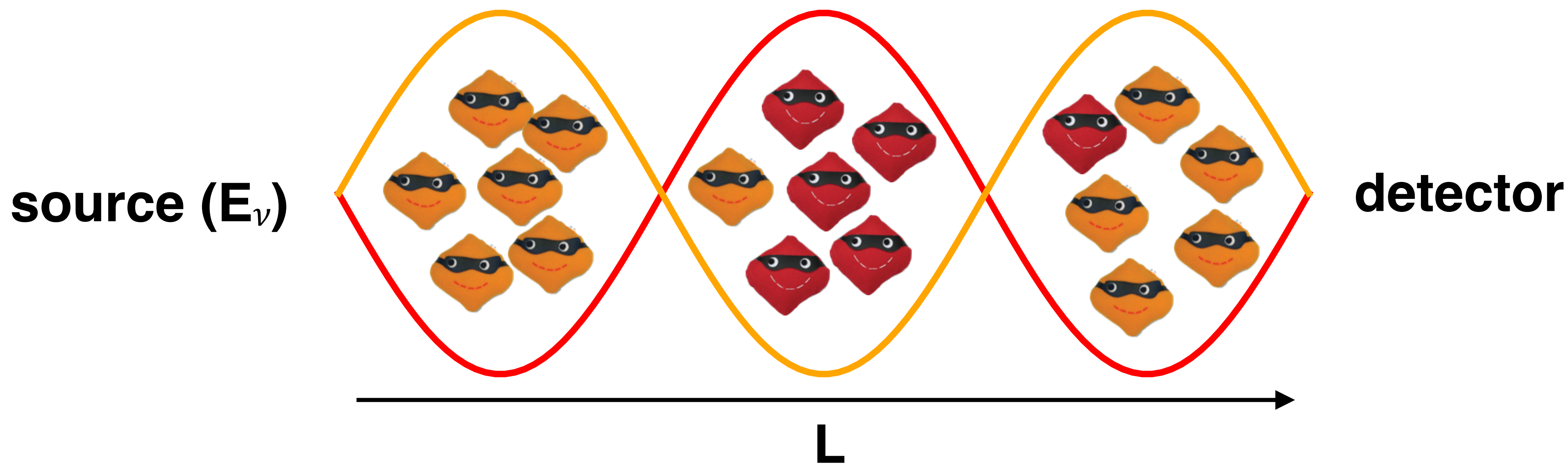
atmospheric/accelerator *reactor* *solar*

$$U = \begin{pmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & -s_{23} & c_{23} \end{pmatrix} \begin{pmatrix} c_{13} & 0 & s_{13}e^{-i\delta} \\ 0 & 1 & 0 \\ -s_{13}e^{i\delta} & 0 & c_{13} \end{pmatrix} \begin{pmatrix} c_{12} & s_{12} & 0 \\ -s_{12} & c_{12} & 0 \\ 0 & -0 & 1 \end{pmatrix}$$

$$where\ \ c_{ij} = cos(\theta_{ij})$$
$$s_{ij} = sin(\theta_{ij})$$
$$\delta = CP\ phase$$

Ex: Two Neutrino Oscillation

$$P_{\alpha\to\beta,\alpha\neq\beta} = sin^2(2\theta)sin^2\left(\frac{\Delta m^2 L}{4E_\nu}\right) \;\; where \;\; \alpha,\beta = \nu_e,\nu_\mu,\nu_\tau$$

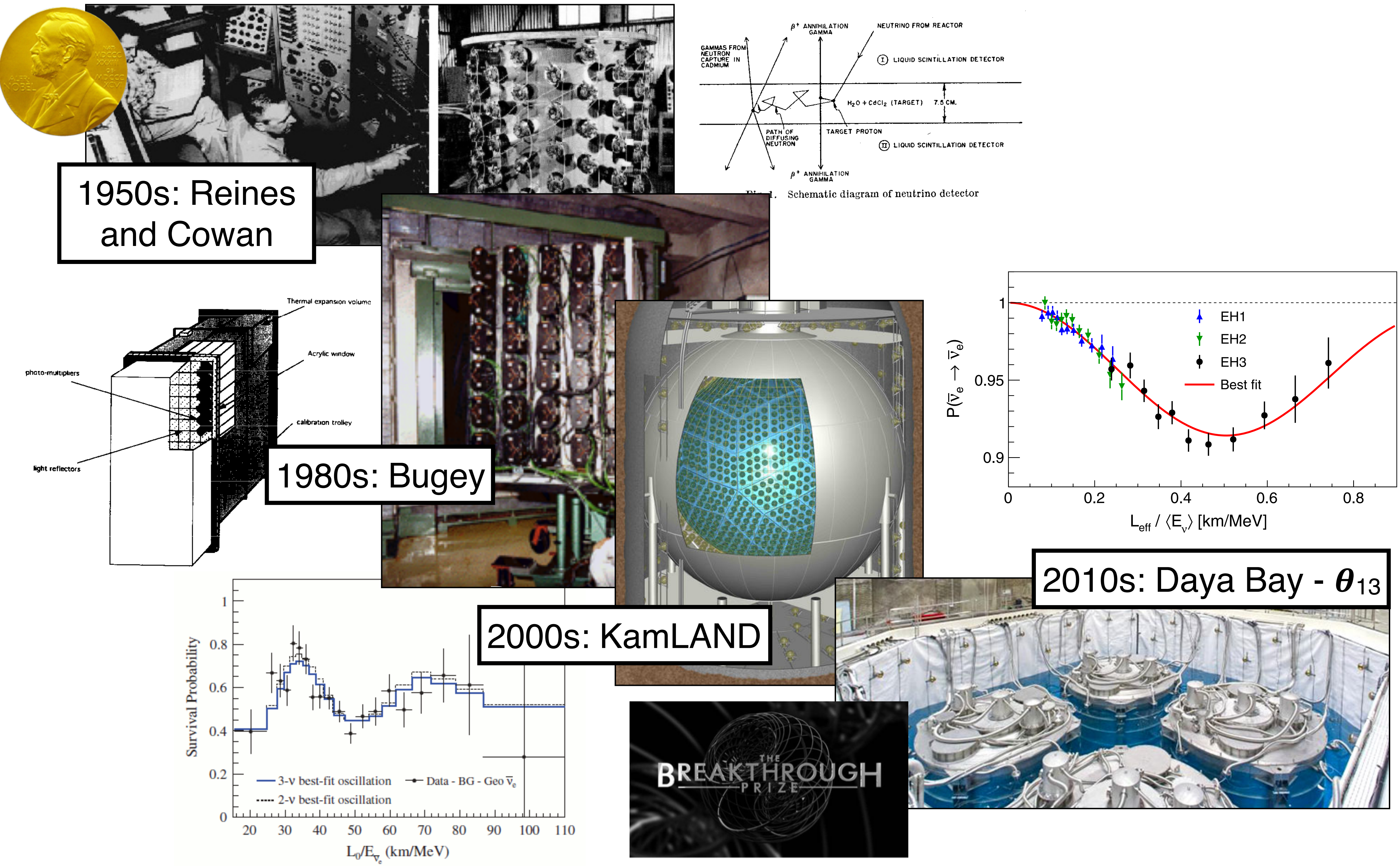


Parameters θ (mixing angle - amplitude) and Δm^2 (mass splitting - frequency) are defined by nature. We can target specific Δm^2 measurements by designing our experiments to have a certain L/E.

Outline

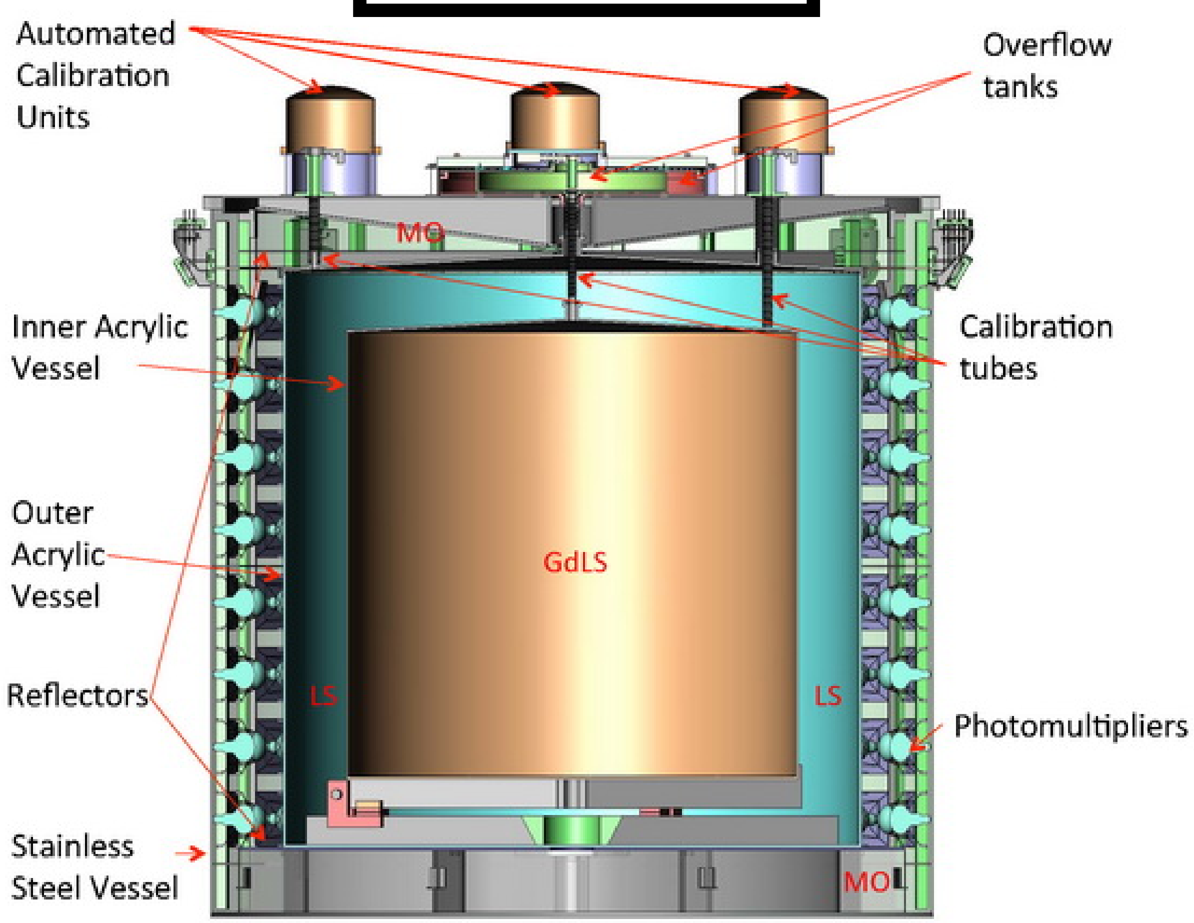
- ~~Neutrinos in the Standard Model~~
- Reactor neutrinos and new anomalies
- **PROSPECT**: The Precision Reactor Oscillation and Spectrum Experiment
- Current efforts

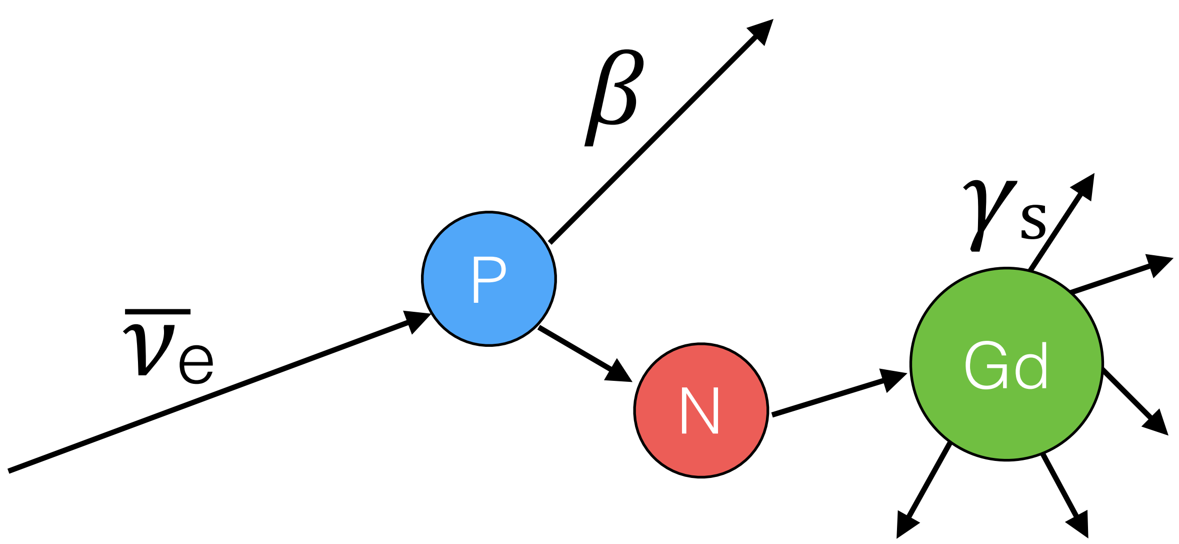
Reactors: Tools for discovery



Detecting Reactor Neutrinos

Daya Bay





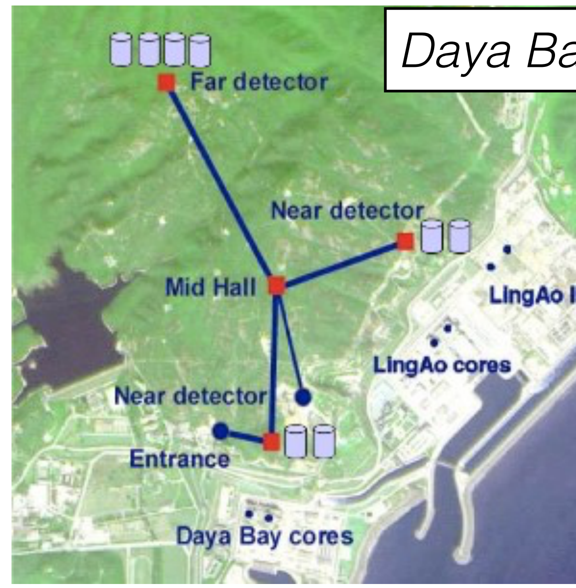
Inverse Beta Decay: $\overline{\nu}_e p \to e^+ n$

- 0.1%Gd-Loaded Organic liquid scintillator (GdLS) surrounded by photomultiplier tubes
- Neutrinos interact with free protons
- $E_\nu = T_{e+} + T_n + (m_n - m_p) + m_e \approx T_{e+} + 1.8\text{MeV}$
- Neutrino energy threshold of 1.8 MeV, producing signal of ~1MeV
- Capture resulting neutron as a tag of IBD interaction (typically Gd)
- Time-correlated signals, separated by ~10s μs

Precision Reactor Neutrino Physics

Kilometer baseline θ_{13} precision experiments: Daya Bay, Double Chooz, RENO

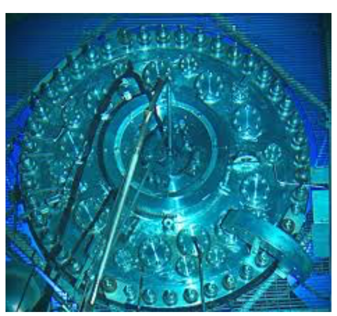
Daya Bay antineutrino detectors



Daya Bay site

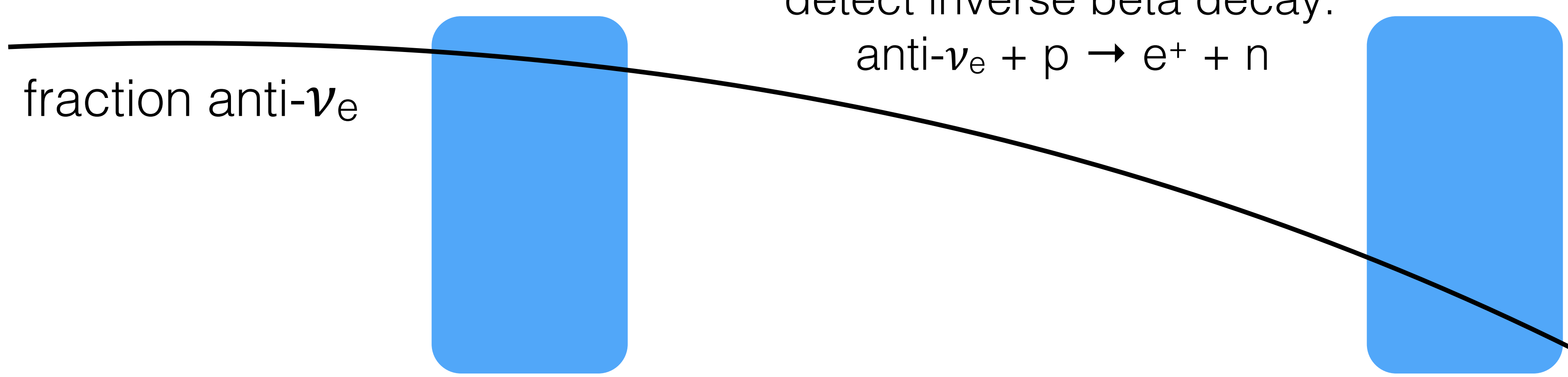
$$P(\bar{\nu}_e \to \bar{\nu}_e) = 1 - sin^2(2\theta) sin^2\left(\frac{\Delta m^2 L}{4E_\nu}\right)$$

survival probability



reactor core

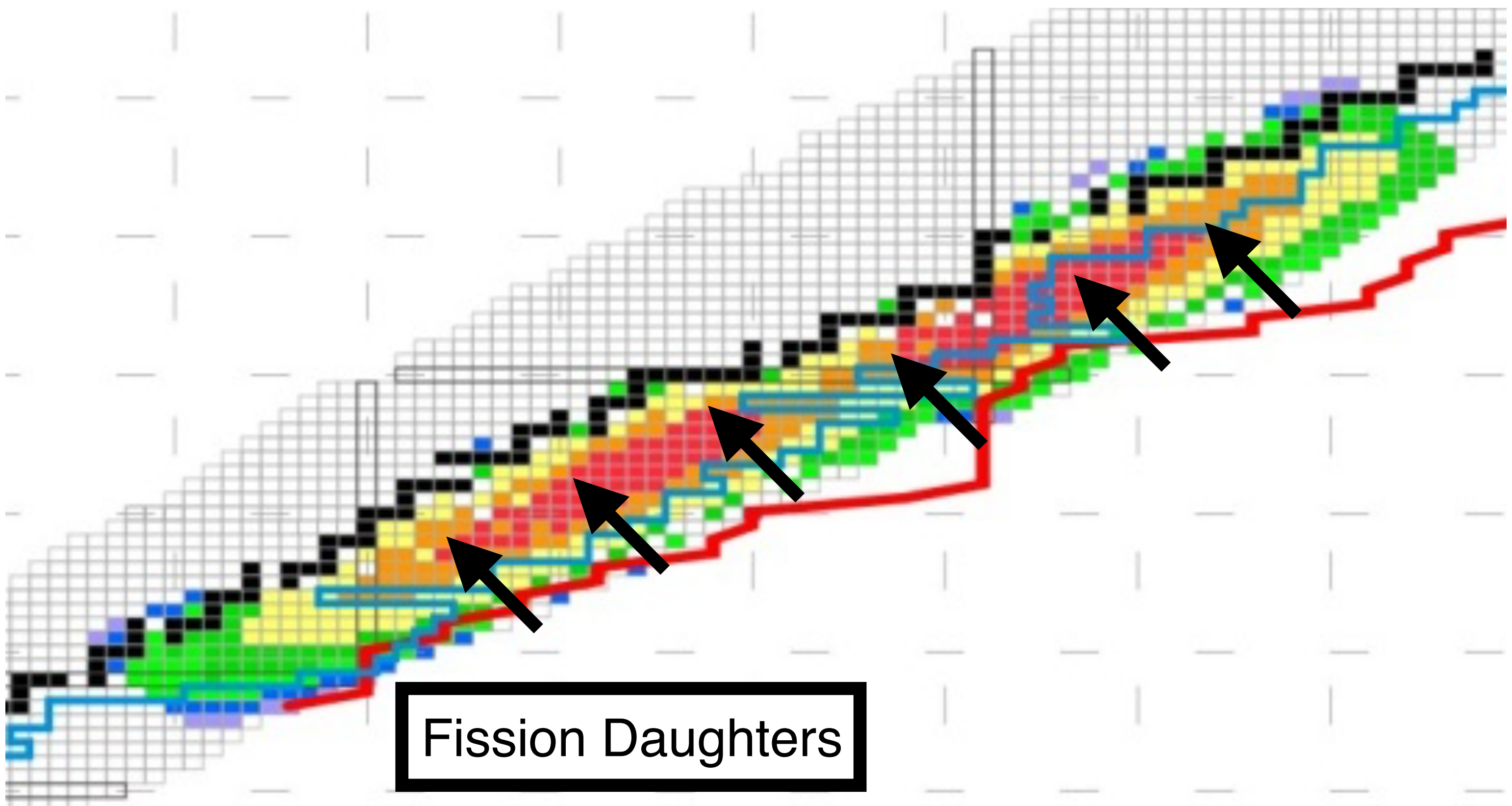
detect inverse beta decay:
anti-ν_e + p → e^+ + n

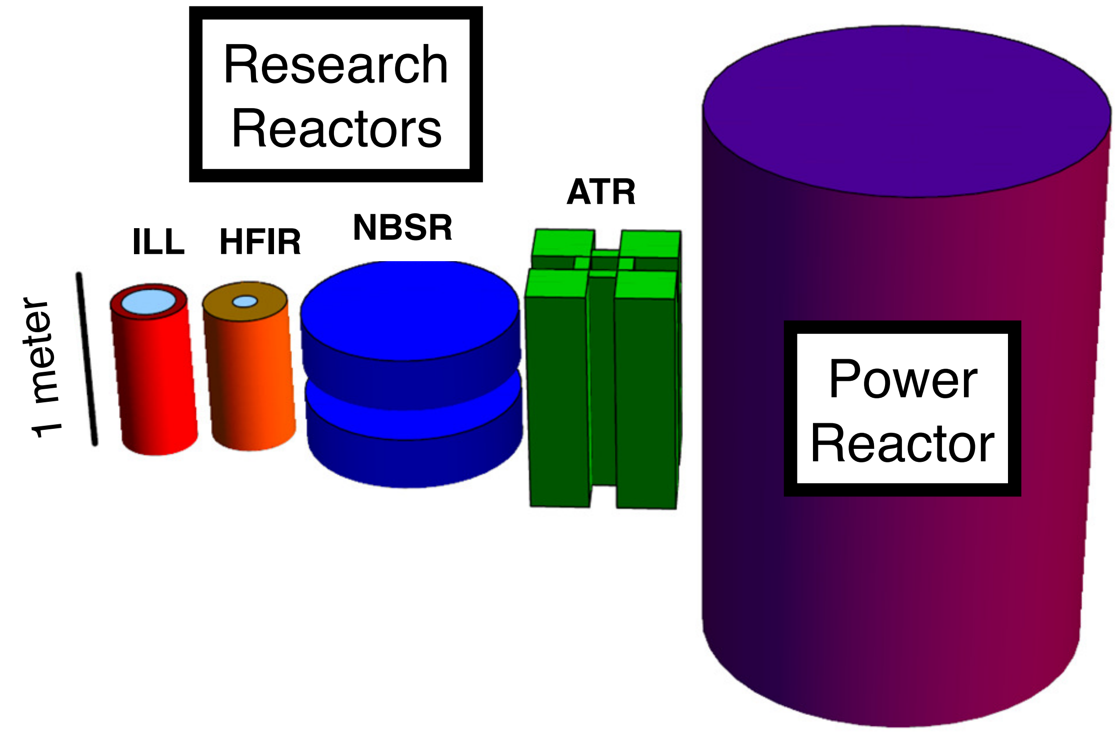


near detector *far detector*

Relative measurements reduce dependence on predictions of reactor properties

Reactor neutrino production





Decay Rate Spectrum

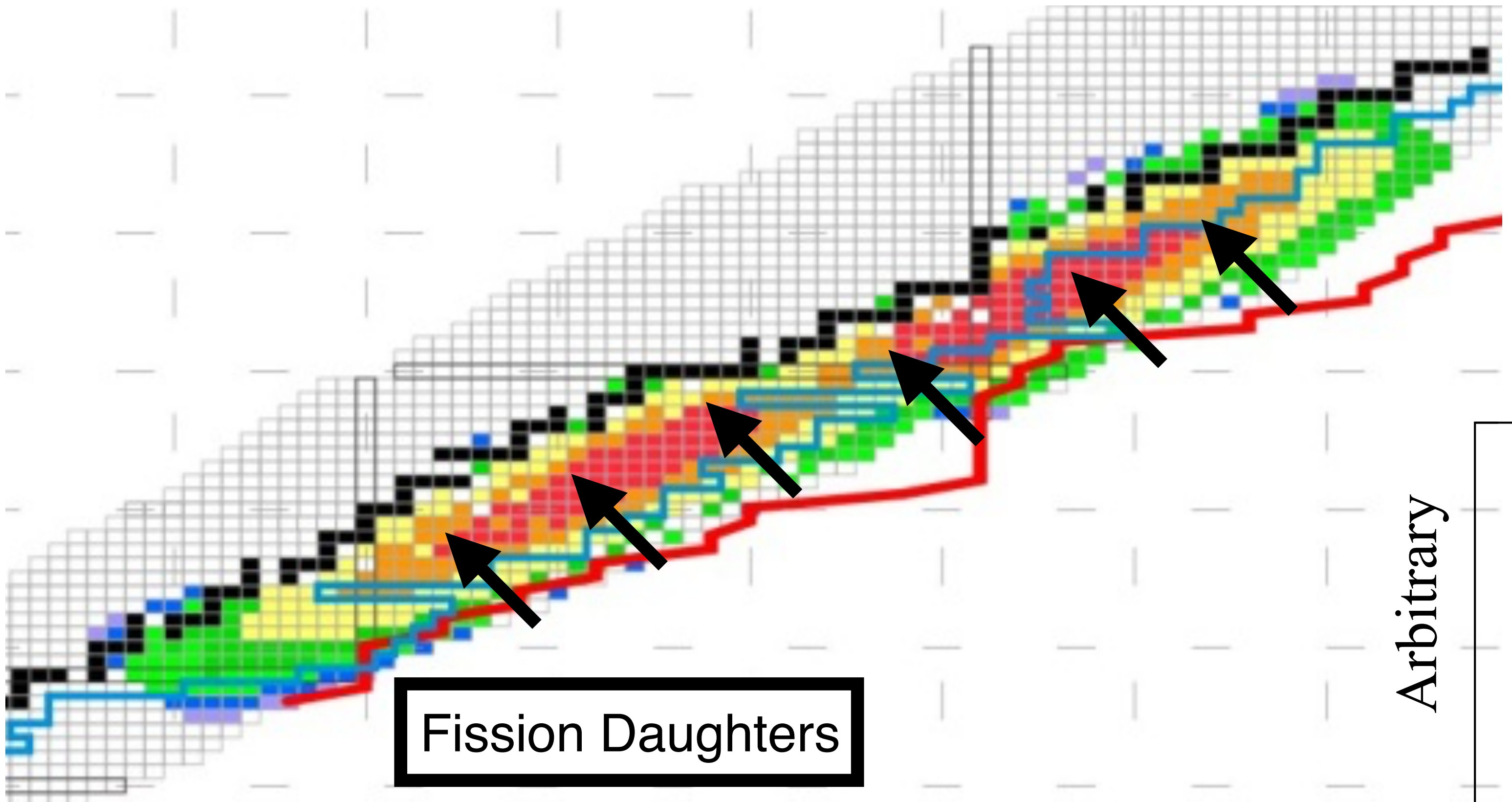
$$S(E_{\bar{\nu}}) = \sum_{i=0}^{n} \boxed{R_i} \sum_{j=0}^{m} \boxed{f_{ij}} \boxed{S_{ij}(E_{\bar{\nu}})}$$

Branching Fraction

- Fission of parent isotopes yield neutron-rich daughters
  - Beta decays produce ~6ν/fission, <10MeV

- Power plants have low-enriched uranium (LEU) cores
  - Mixture of ^{235}U, ^{238}U, ^{239}Pu, ^{241}Pu
- Research Reactors have highly-enriched cores: mainly ^{235}U

Reactor neutrino production



Decay Rate

Spectrum

$$S(E_{\bar{\nu}}) = \sum_{i=0}^{n} \boxed{R_i} \sum_{j=0}^{m} \boxed{f_{ij}} \boxed{S_{ij}(E_{\bar{\nu}})}$$

Branching Fraction

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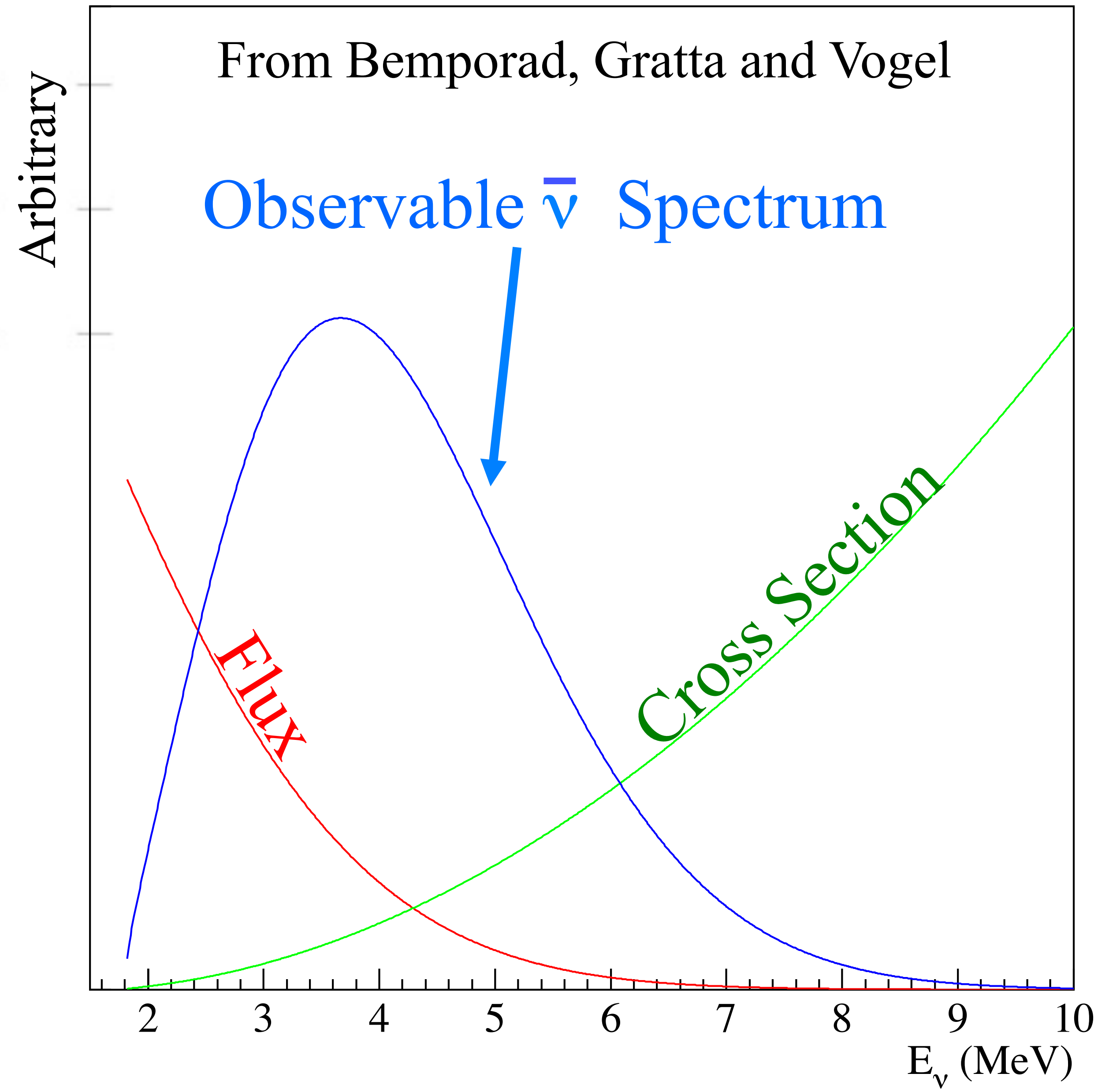
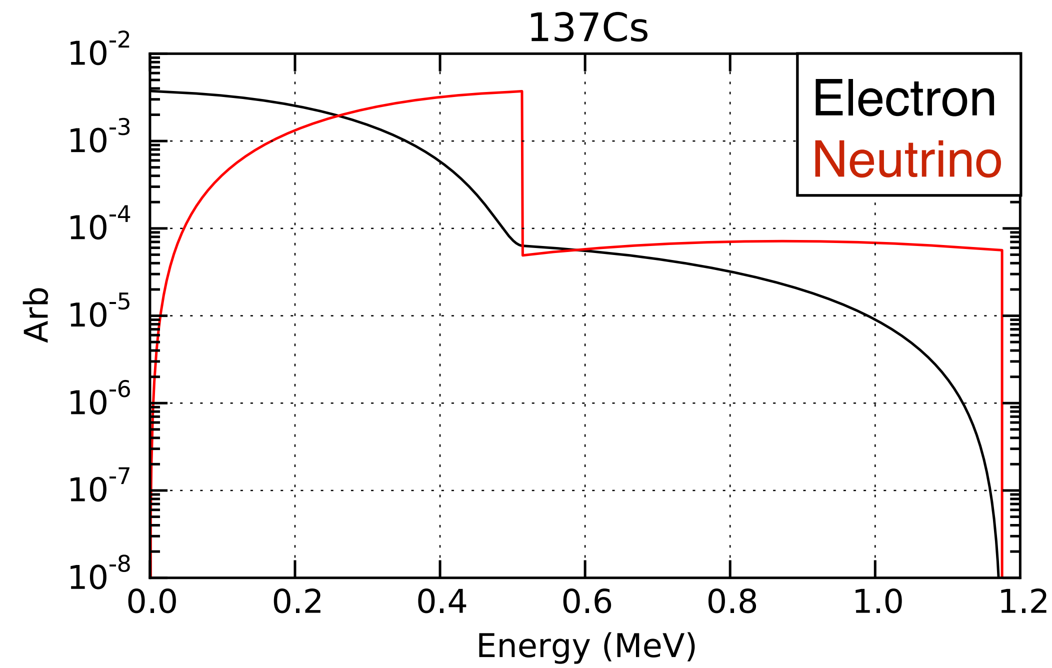
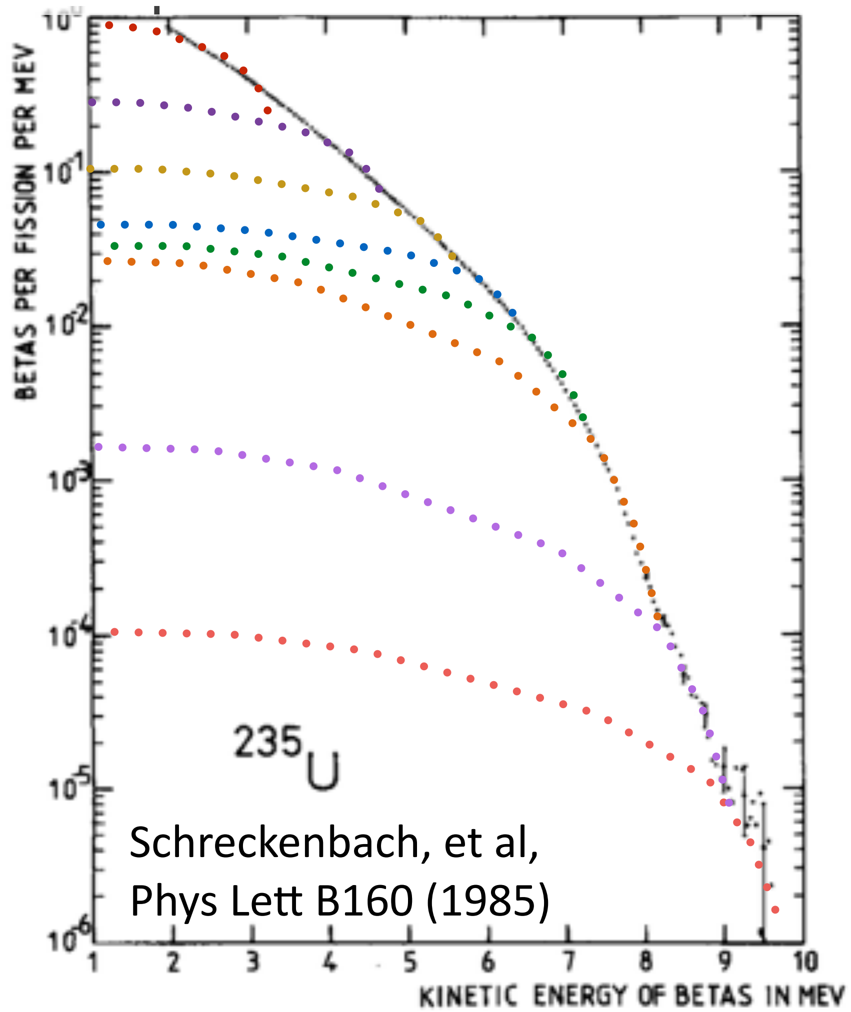


Predicting Neutrino Flux/Spectra

Two main approaches:

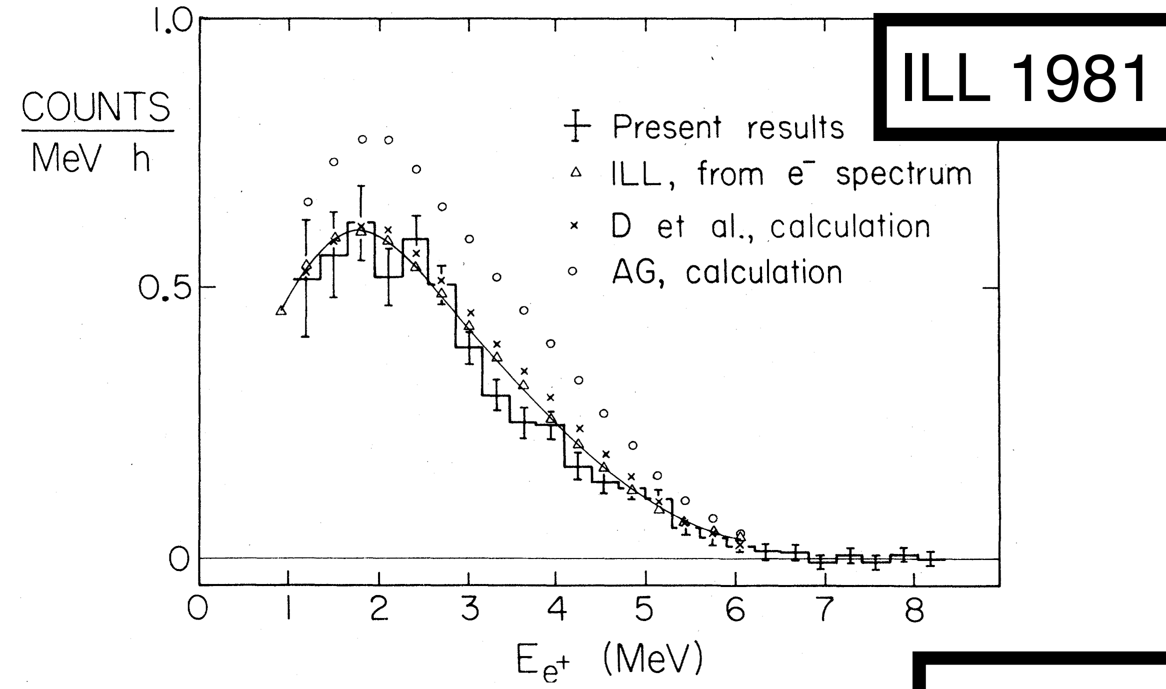
- ***Ab-initio***
  - Calculate individual beta-decay spectra for 1000s of isotopes from database info
  - Sum according to cumulative yields
  - **Problem:** databases have huge uncertainties
- ***Beta-conversion***
  - Measure cumulative beta spectra from fission parents
  - Use virtual beta-branches to convert into neutrino spectra
  - **Problem:** can virtual branches capture all relevant physics?

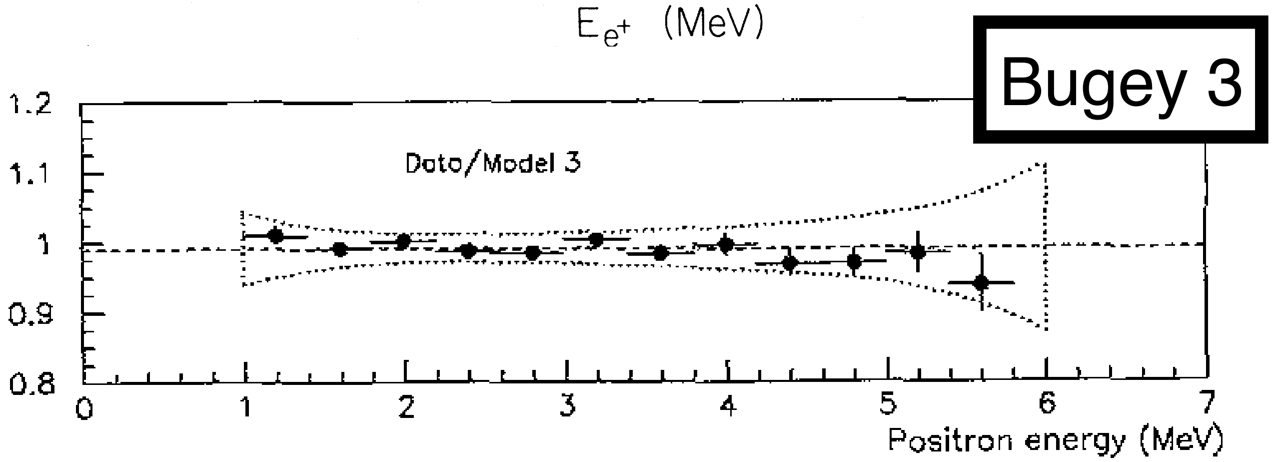


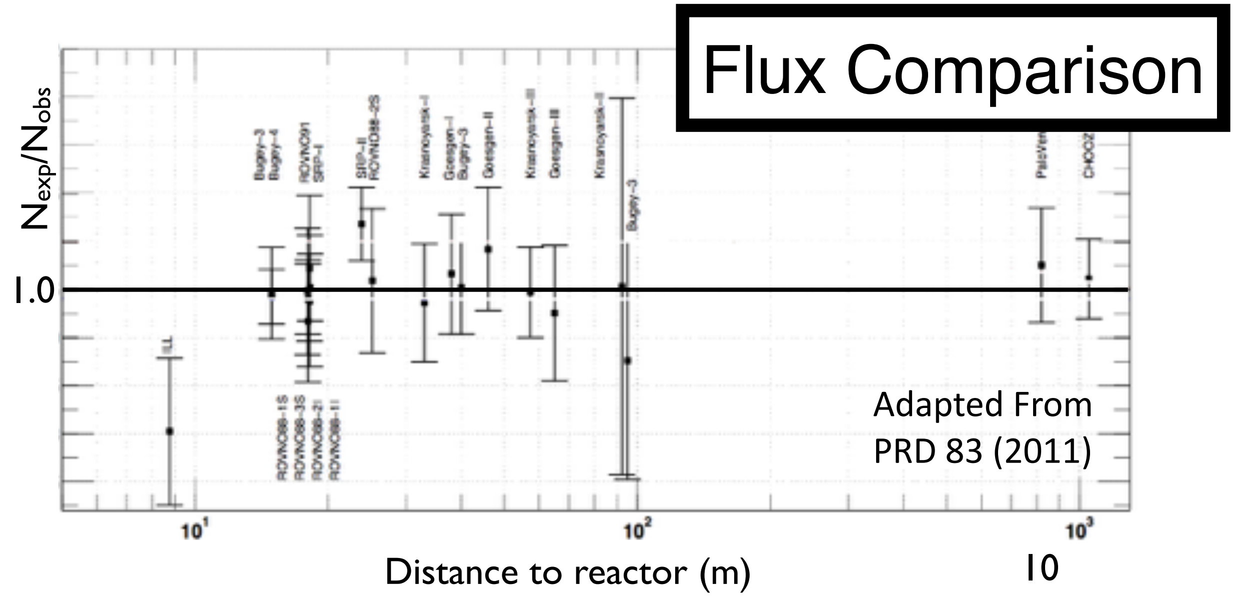


Predicting Neutrino Flux/Spectra

- **Early 1980s:** Measurement of ^{235}U spectrum at Institut Laue–Langevin (ILL)
  - Agrees with ab-initio calculations
  - <5000 neutrinos detected, 20% uncertainties
- **Mid 1980s:** Beta-conversion measurements at ILL, reduce systematics improve uncertainties or predictions
- **1990s:** Bugey PWR spectrum agrees with Beta-conversion spectra
- **1990-2000s:** Measured fluxes agree with predictions



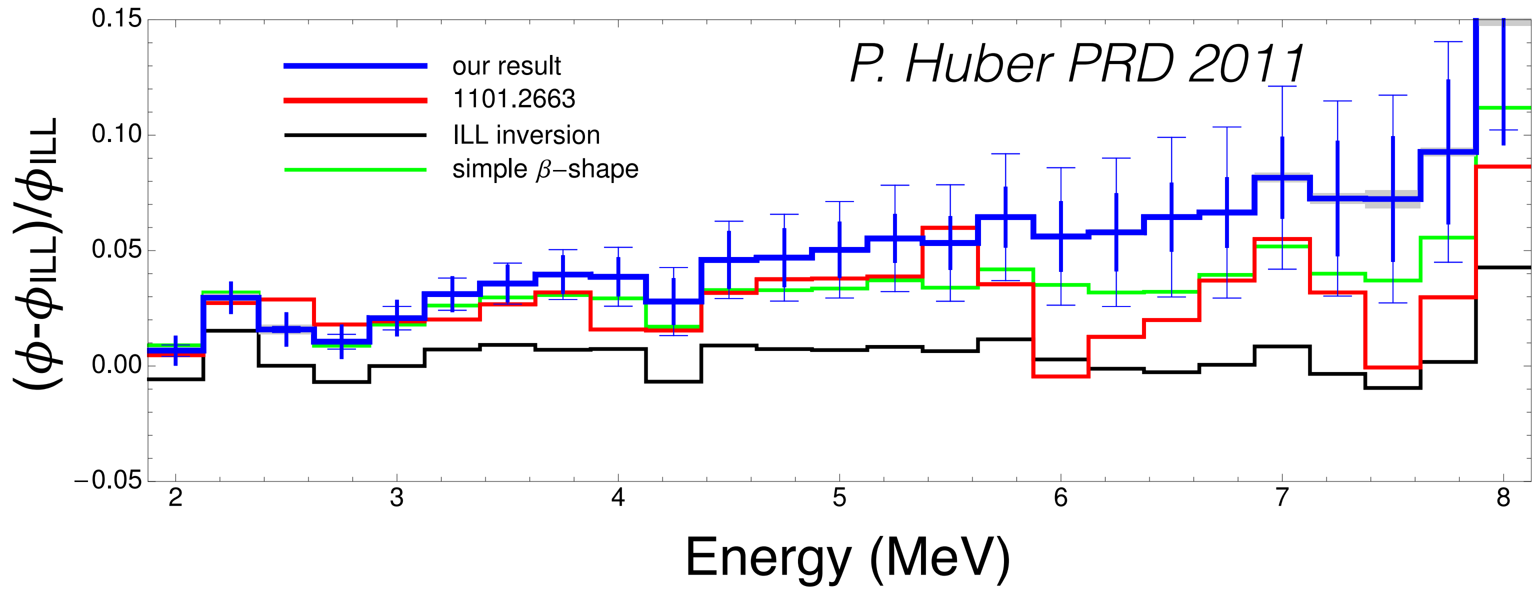


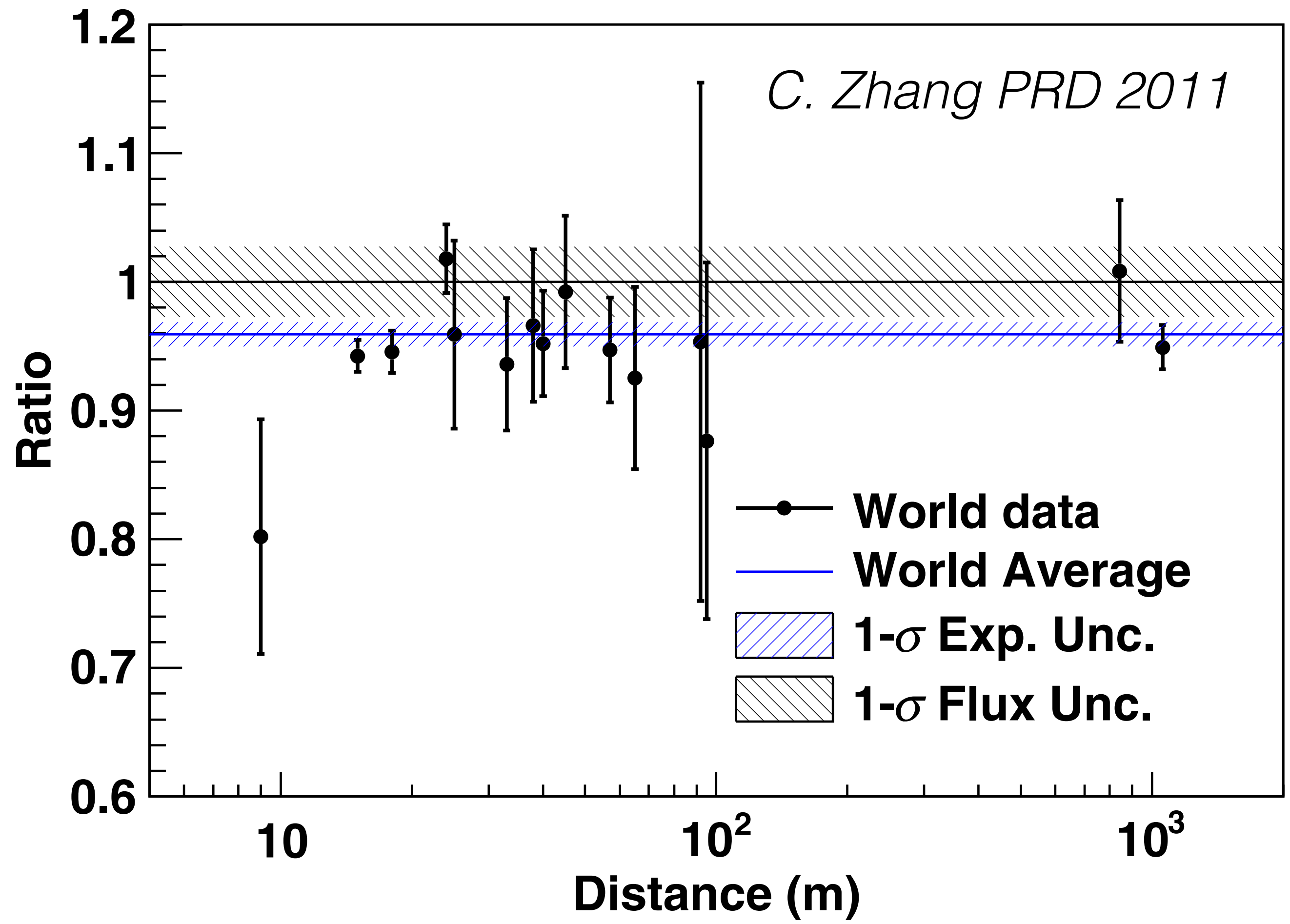


Adapted From PRD 83 (2011)

Recent Events: Problems emerge

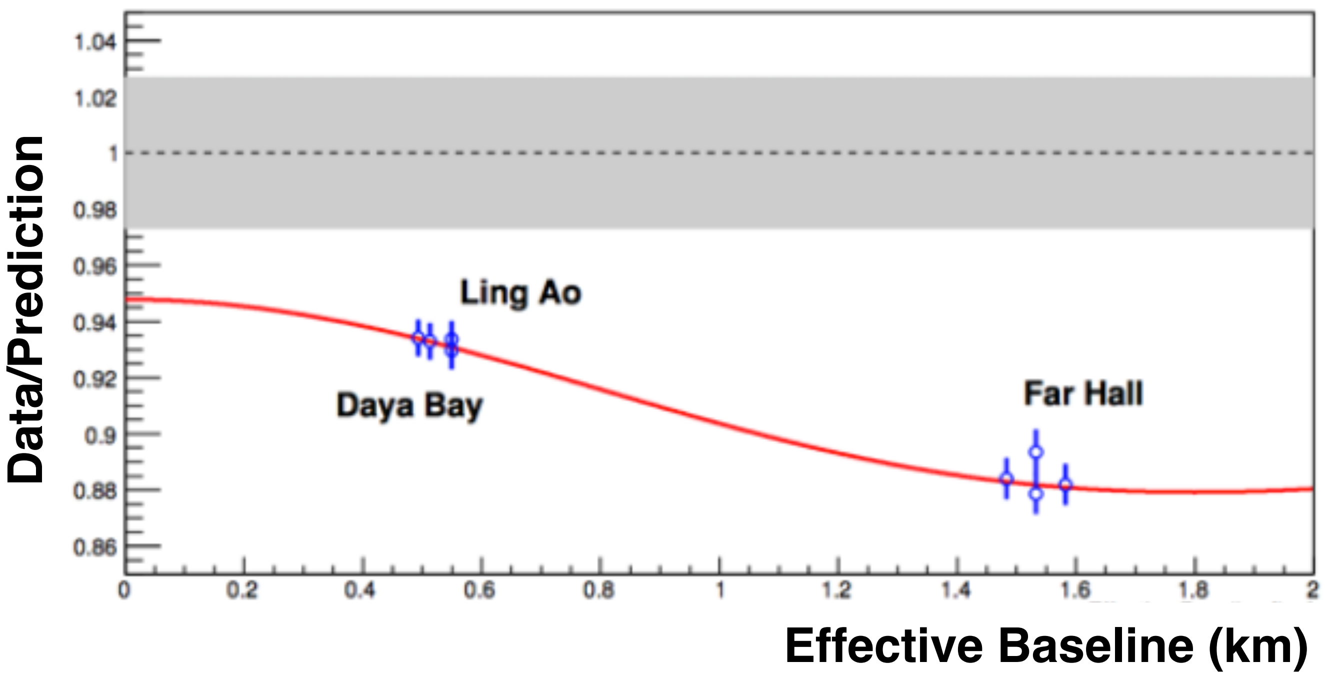
- **2011:** Two beta-conversion reanalyses increase predicted flux
  - One pure conversion, one hybrid between ab-initio and conversion
  - $\sim 3\sigma$ tension with previous experiments
- **Change in Flux/Spectrum:**
  - Conversion: +3%
  - Neutron lifetime: +1%
  - Non-equilibrium isotopes: +1%
- **Could be bias from non-blind analyses?**

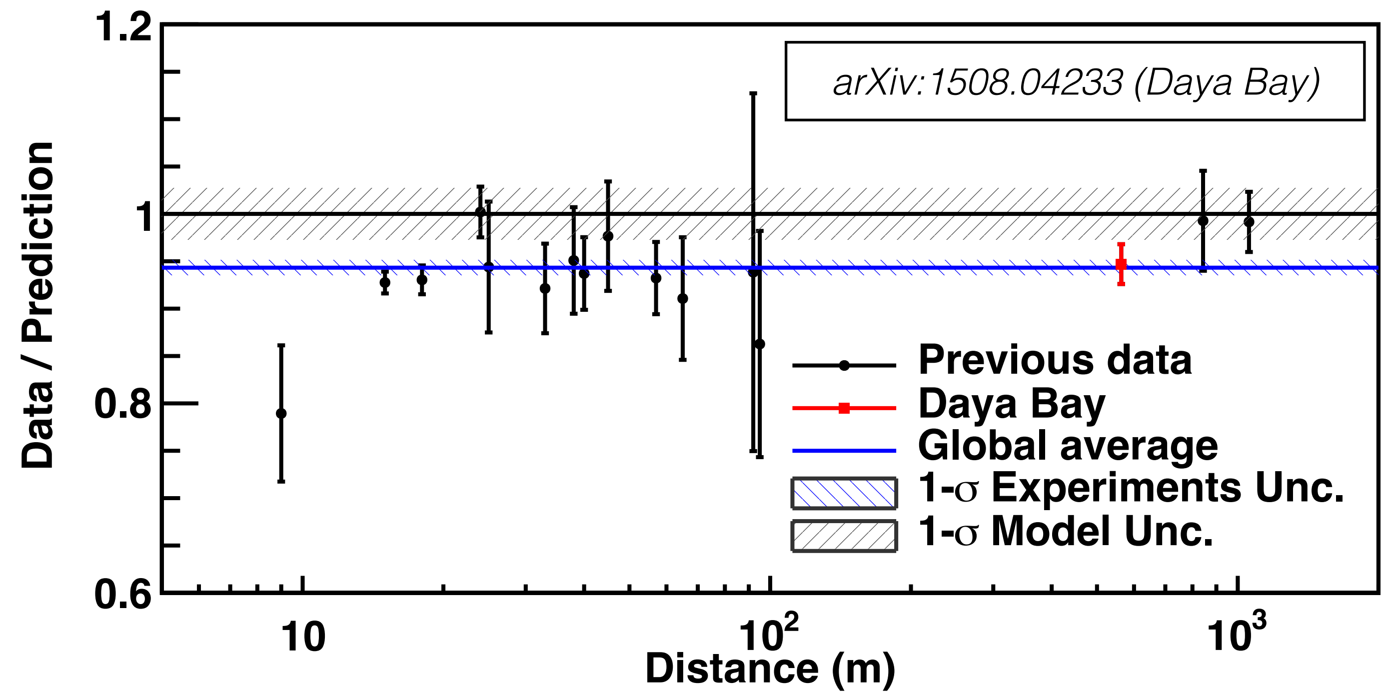




Flux Deficit at Daya Bay

PROSPECT



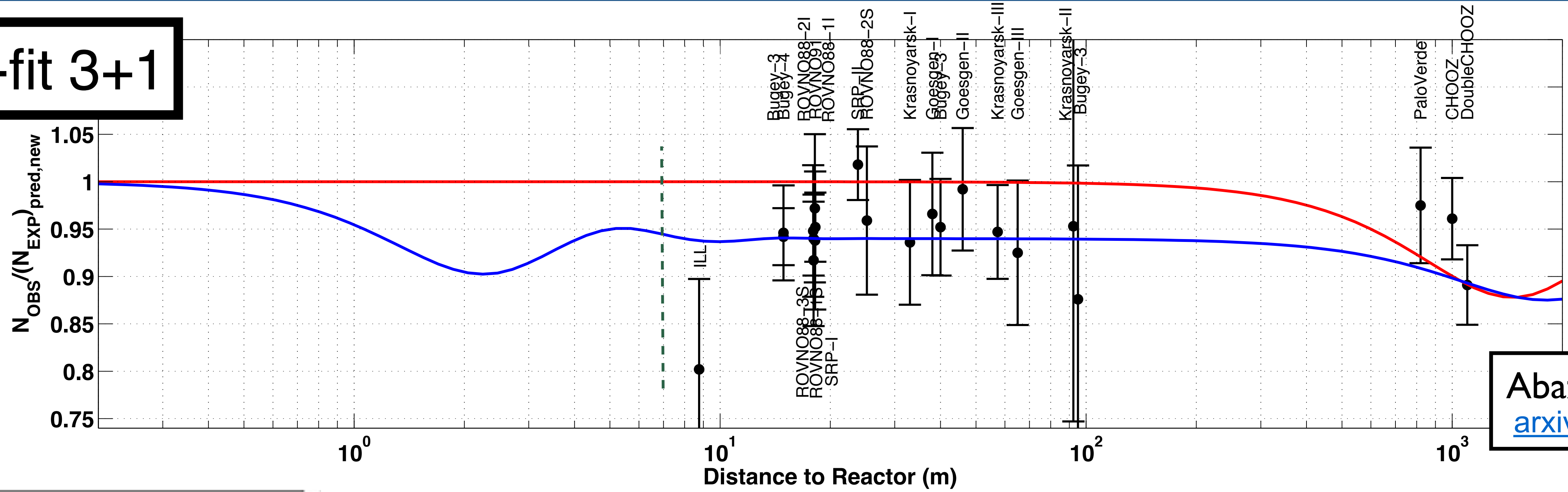


Blind analysis of absolute flux agrees with old prediction

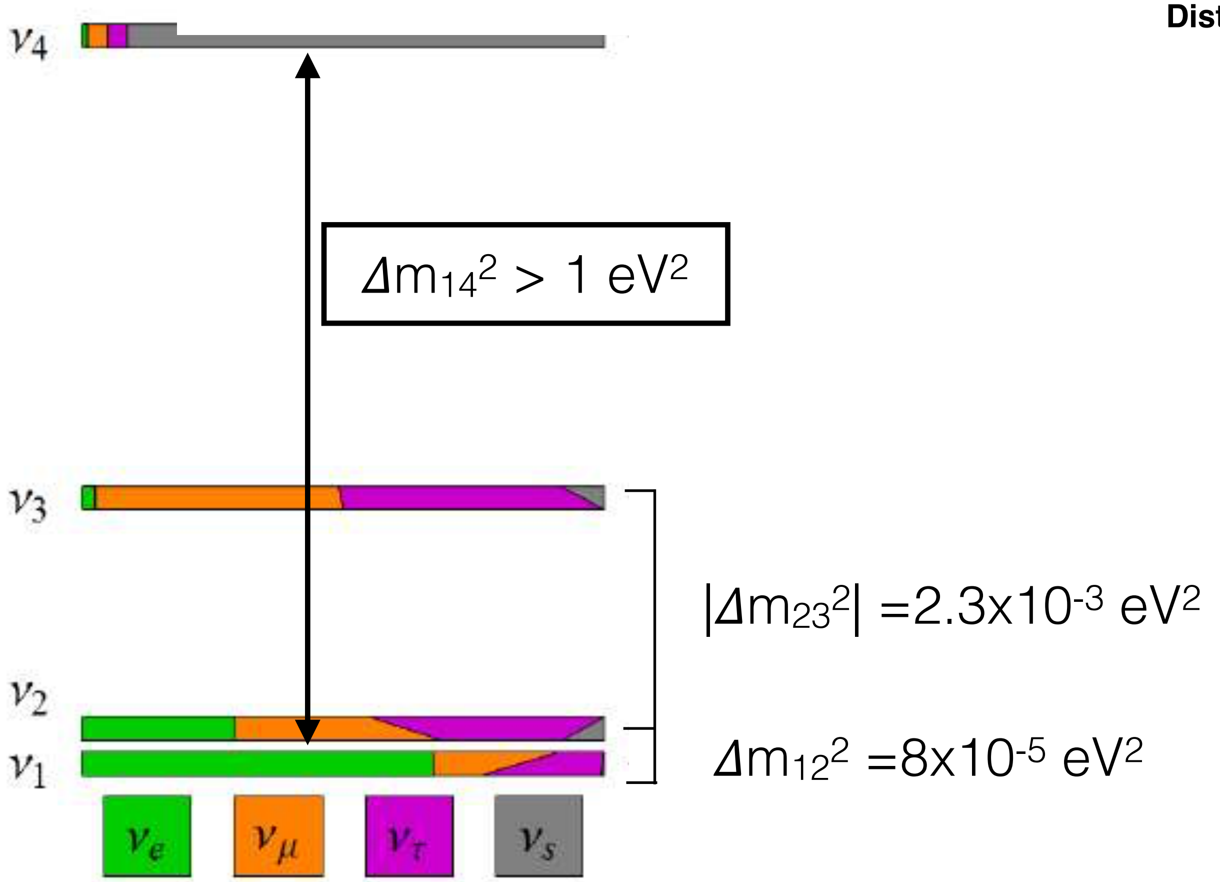
Unlikely to be due to experimental bias

Sterile Neutrinos??

Best-fit 3+1



Abazajian et al.
arxiv:1204.5379



If not a bias effect, what is it?

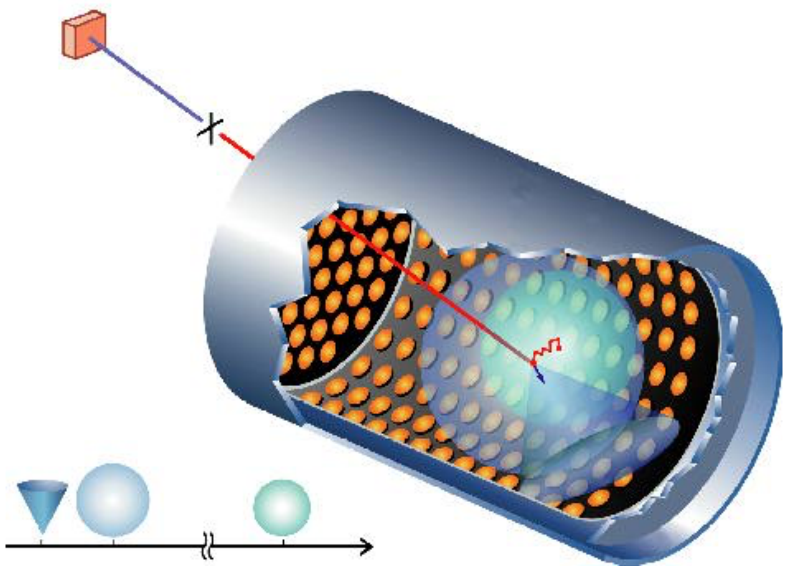
- Problem with prediction?
- Detector effect that isn't understood?
- *New physics?*

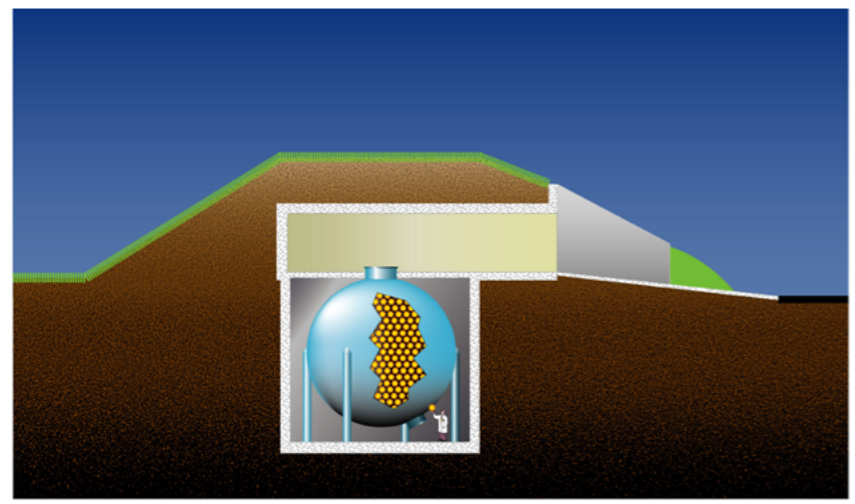
Sterile Neutrino:

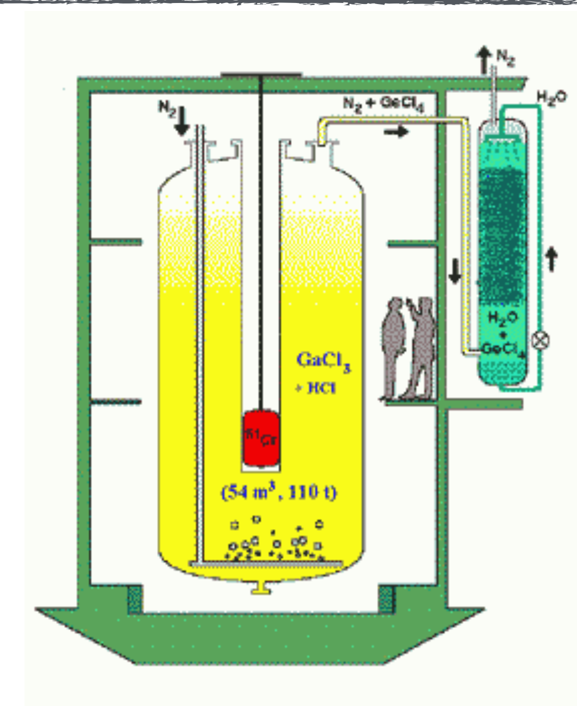
- High frequency oscillation
- Mass splitting ~1eV^2
- Baseline ~few meters

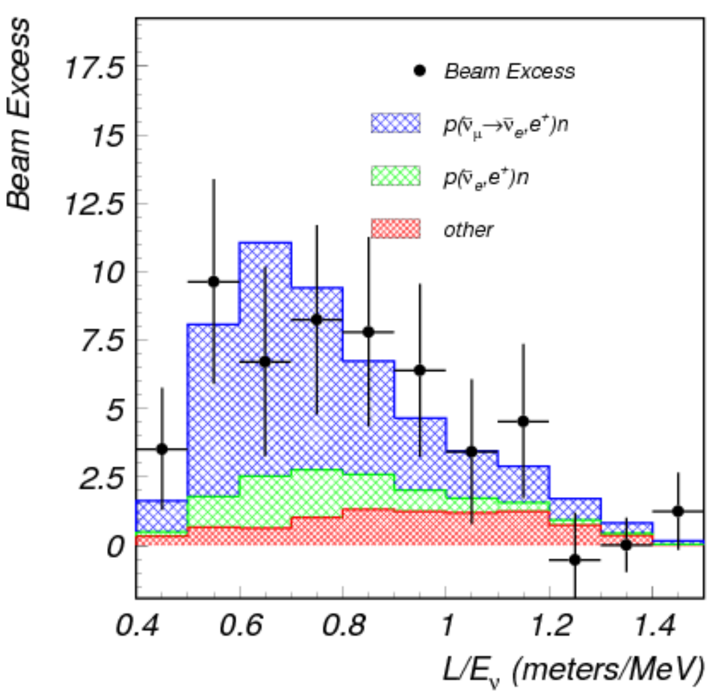
Other Sterile Neutrino Hints

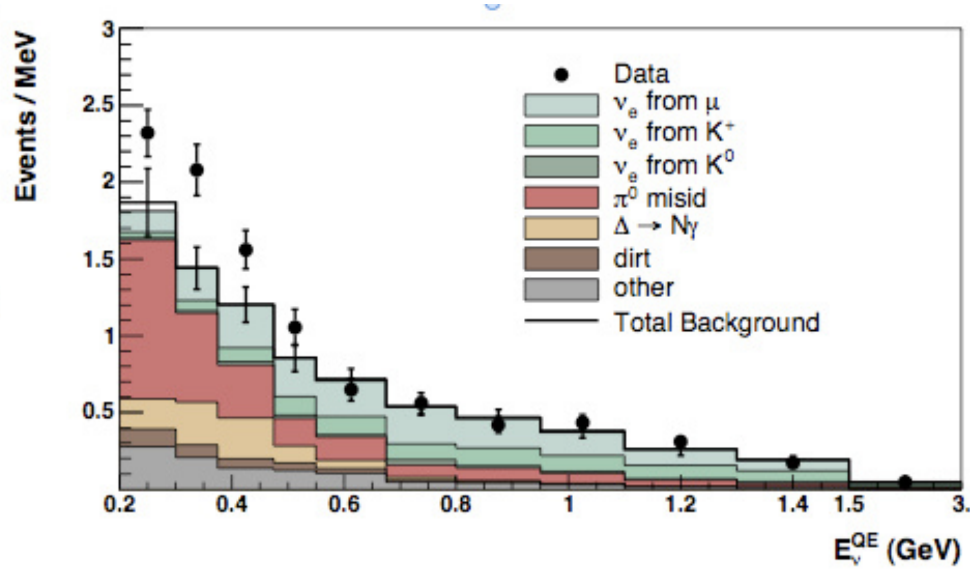
LSND	MiniBooNE	GALLEX/SAGE
decay at rest	short baseline accelerator	Ga source calibration

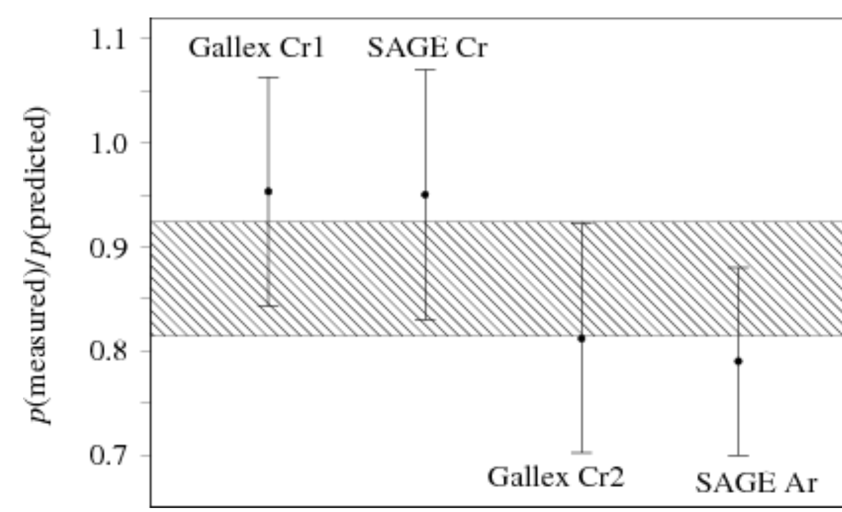












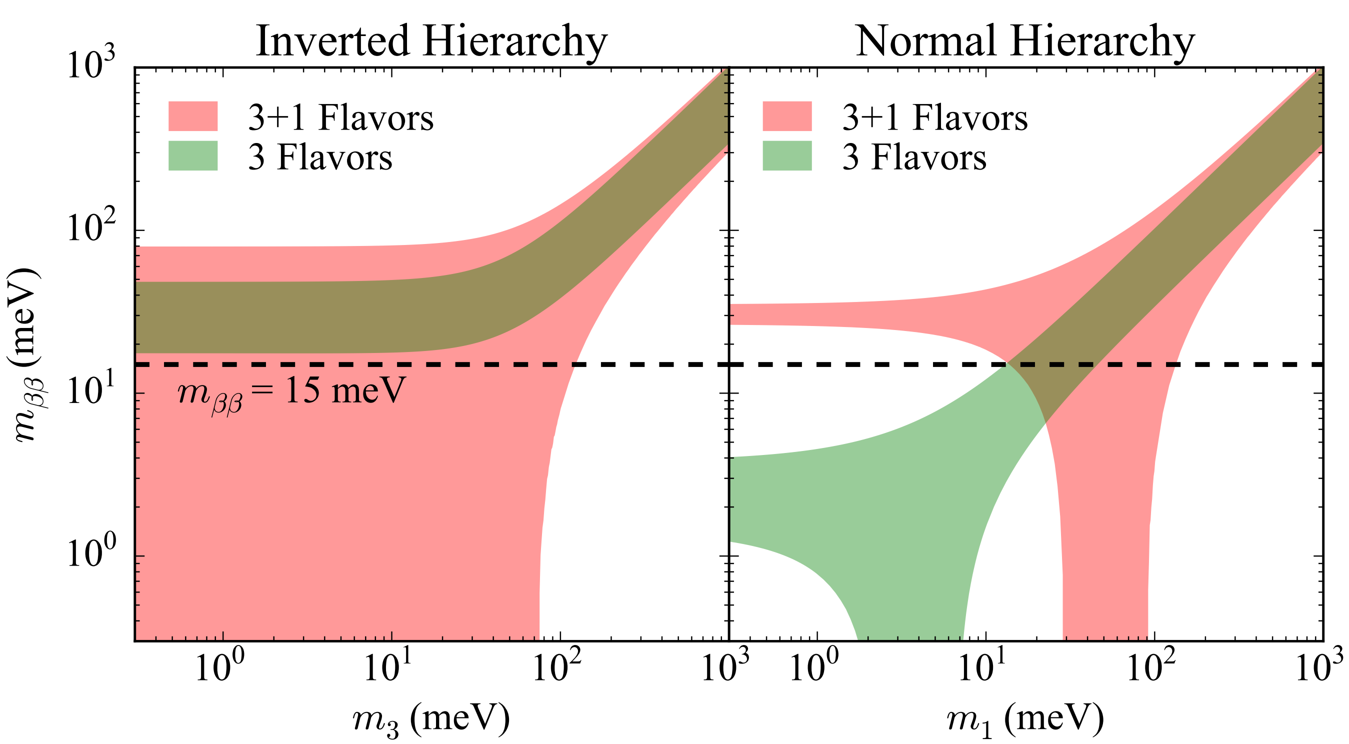
anti-ν_e appearance | **low energy ν_e appearance** | **ν_e disappearance**

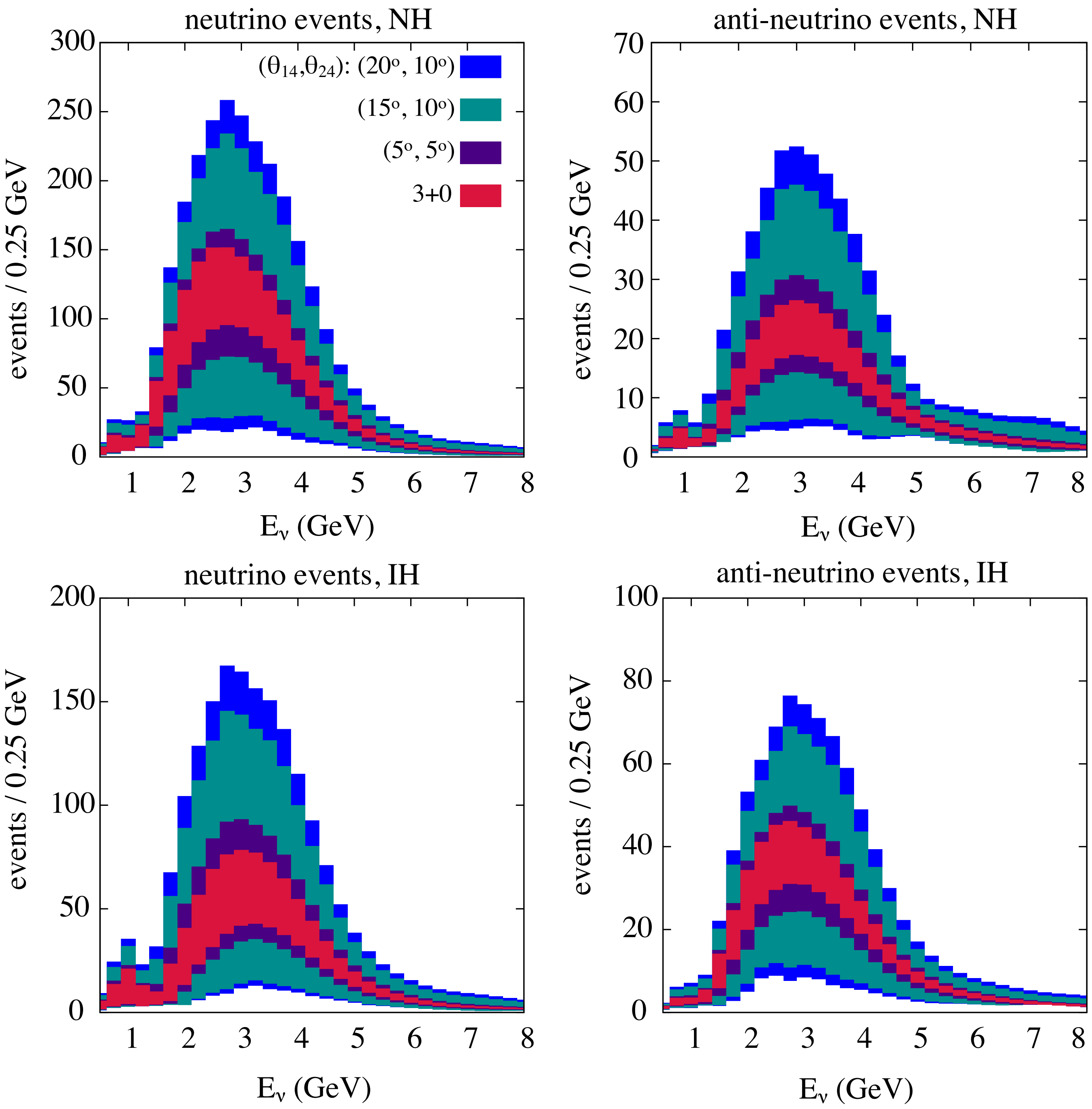
Impact on Future Experiments

eV-scale neutrinos would impact:

- Expected neutrino spectrum for Long-baseline oscillation searches
- Mass ordering for Double Beta Decay searches

Needs to be addressed soon

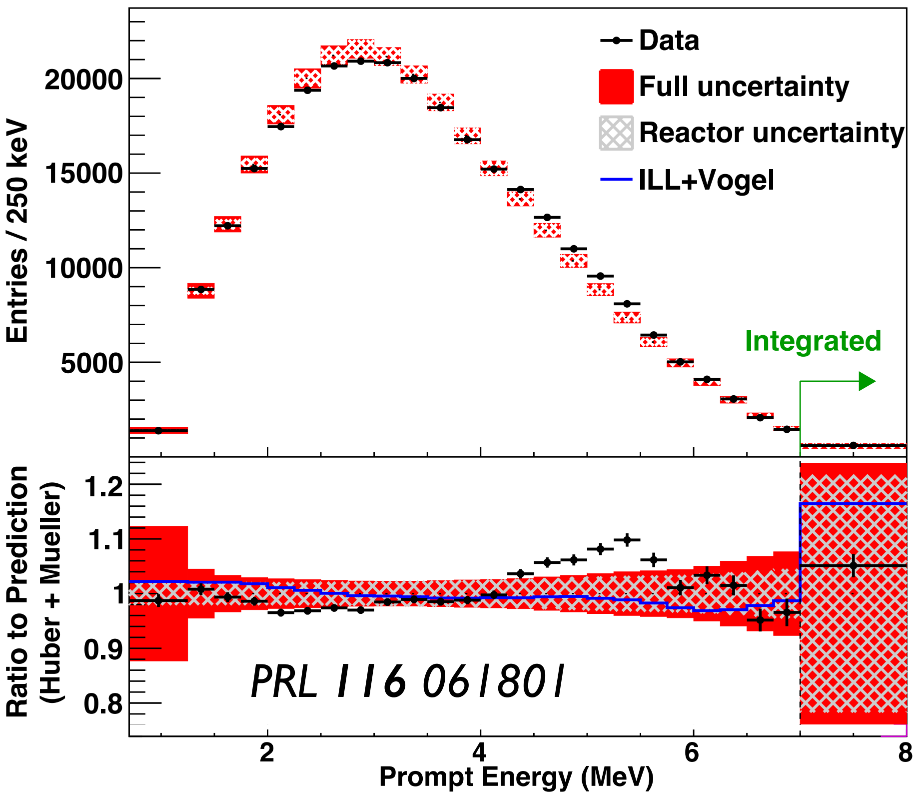




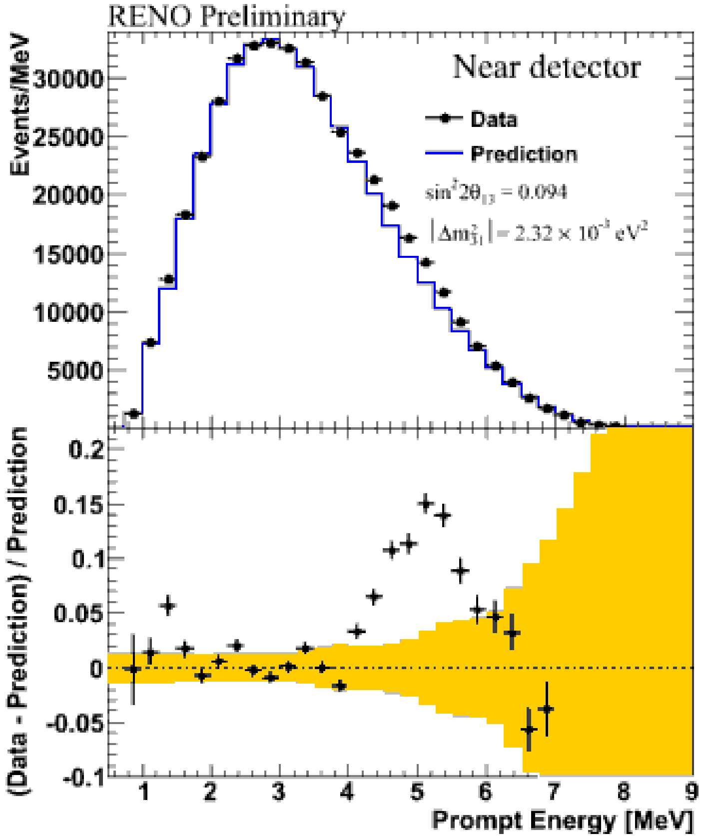
Gandhi, Kayser, Masud, Prakash
arXiv:1508.06275

New Anomaly: Spectral Feature

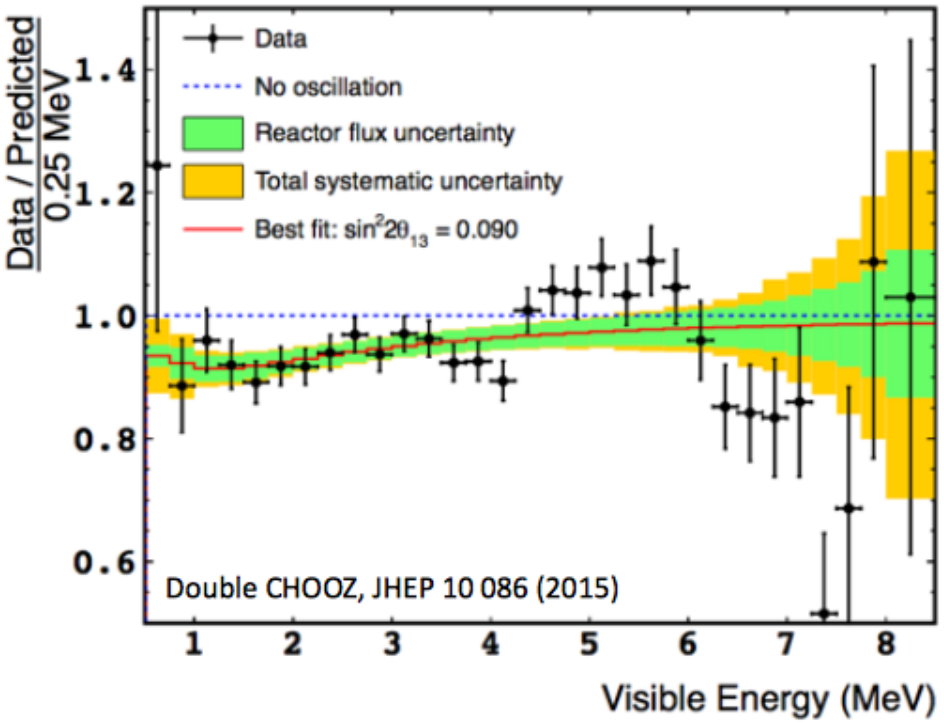
Daya Bay



RENO



Double Chooz



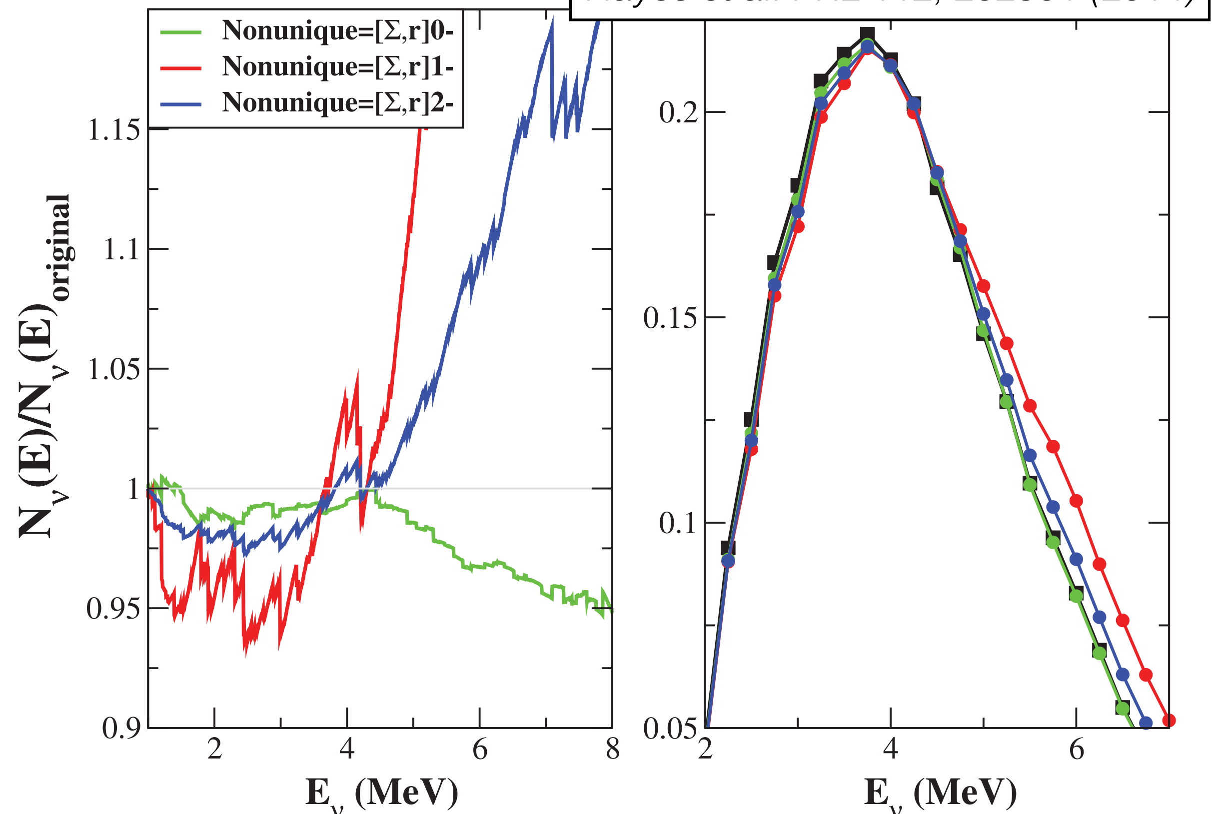
- All three $\boldsymbol{\theta}_{13}$ experiments have observed a spectral deviation between 4-6MeV prompt energy (5-7MeV neutrino energy)
- Predictions based on beta-conversion (Huber, Mueller, Haag)
- Tracks with reactor power, observed in both Near and Far detectors
- Cannot be explained by known detector effects

New Anomaly: Spectral Feature

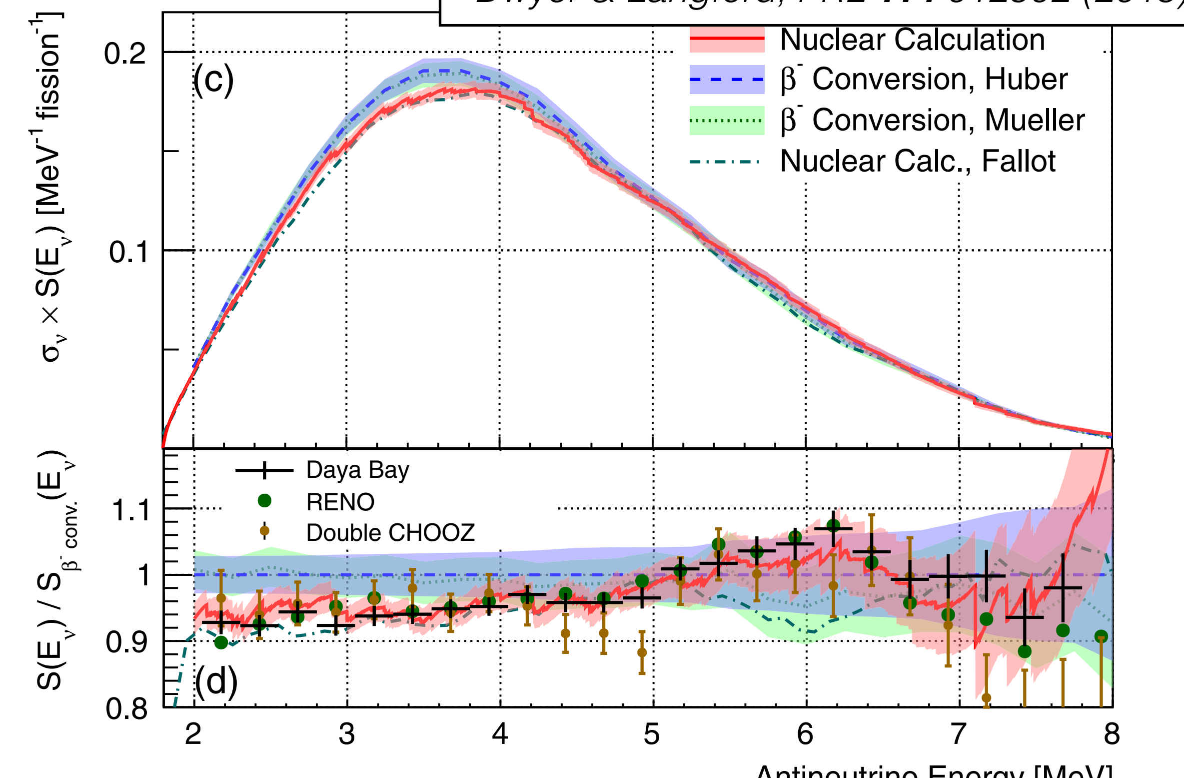
PROSPECT

- **Beta-converted spectra could be wrong:**
  - Use Allowed shapes for all decays, known to be incorrect
  - Error in the measurements?
- Ab-initio calculation for one database seems to reproduce the feature
  - **Problem:** Large uncertainties and missing data
  - **Problem:** More complete database doesn't reproduce the shape
- *Feature seems to track with ^{238}U content, could point to one fission parent as the problem?*

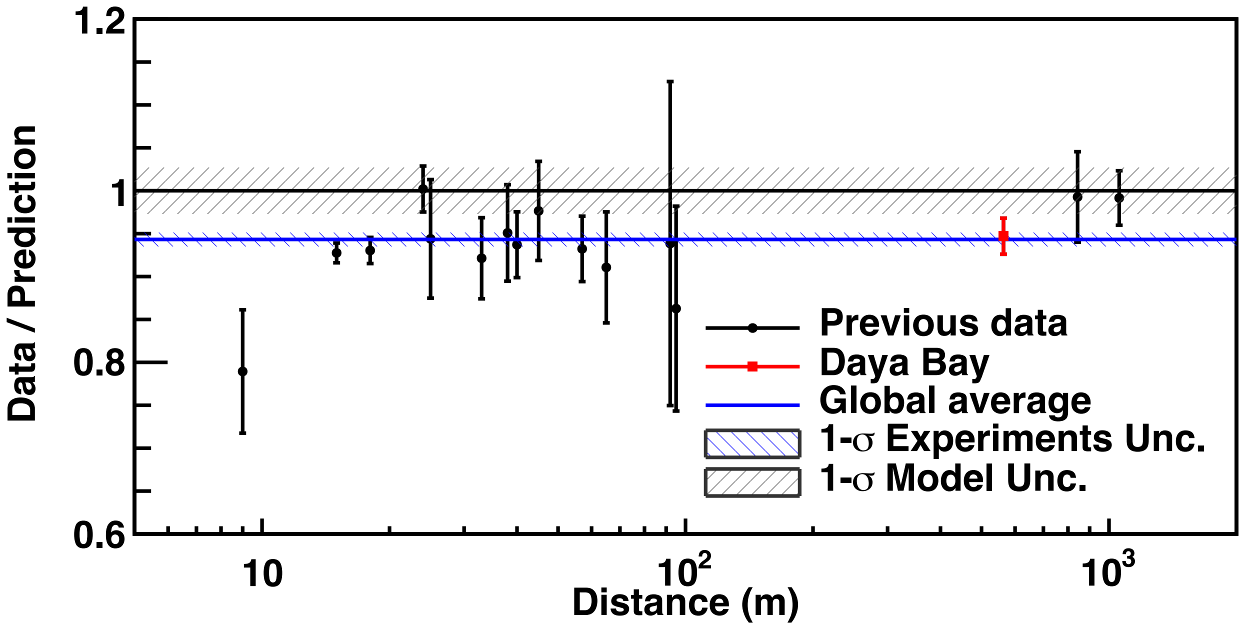
Hayes et al. PRL 112, 202501 (2014)

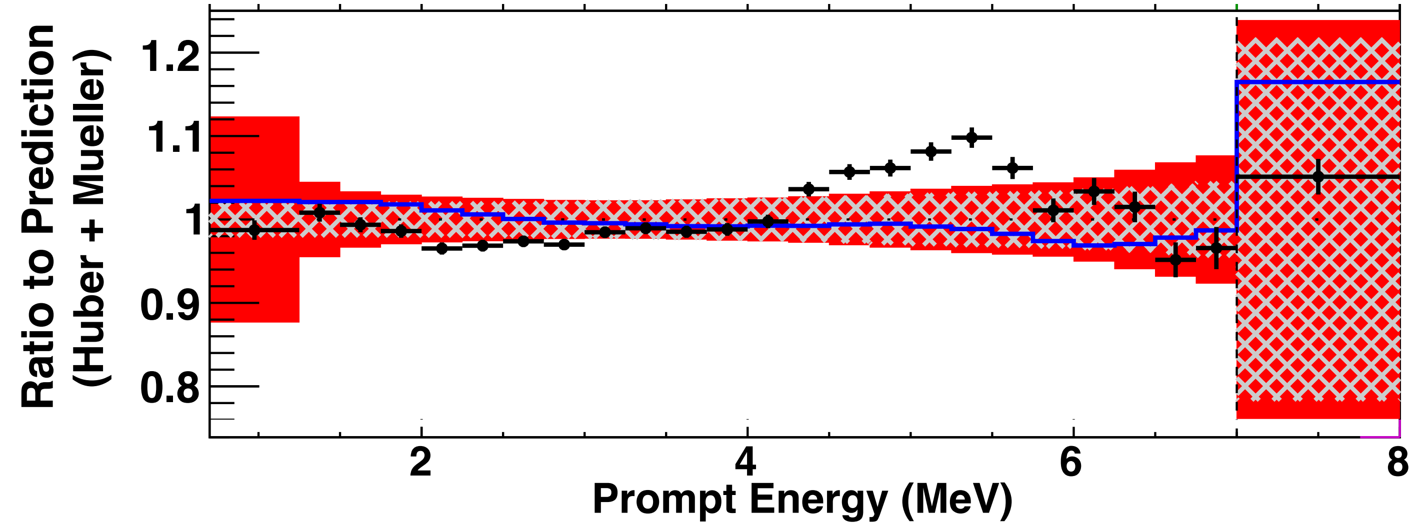


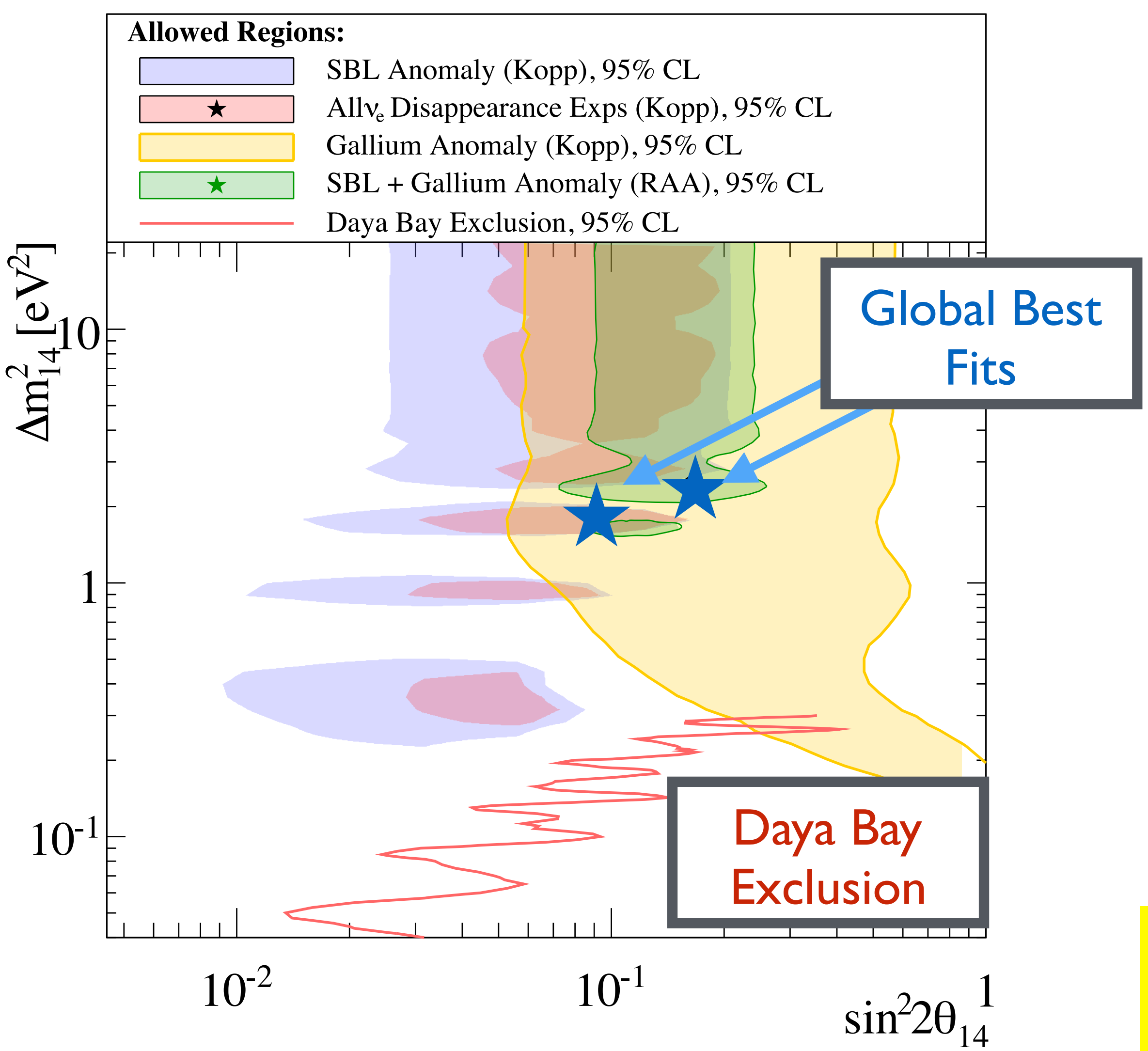
*Dwyer & Langford, PRL **114** 012502 (2015)*



Anomalies lead to Discoveries







- Flux deficit remains after blinded analysis
- No existing experiment is able to probe these questions
- **We need new data**
- Spectral anomaly could point were to look
  - All $\boldsymbol{\theta}_{13}$ measurements at LEU power reactors
  - *HEU measurement powerful crosscheck*

P.Vogel: "…it is possible, perhaps even likely, that both anomalies have their origin in standard physics." arXiv:1603.08990

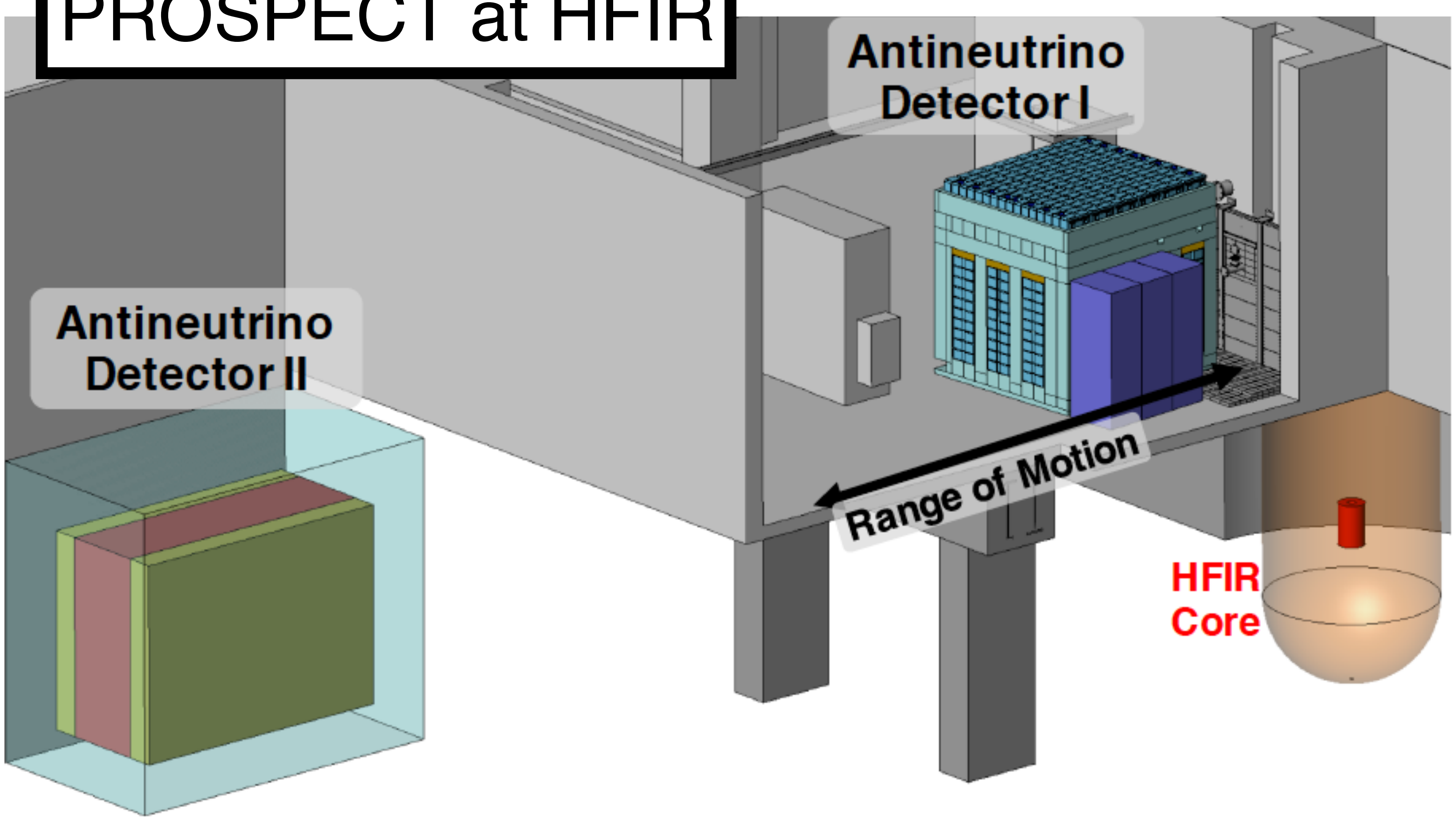
The Precision Reactor Oscillation and Spectrum Experiment

Phased Experimental Plan

Physics Goals:

- Search for short baseline ν_e oscillations using detector segmentation
  - Distortions in energy spectrum that vary with baseline
- Measure ^{235}U antineutrino spectrum to illuminate the spectral anomaly

PROSPECT at HFIR



Experimental Strategy:

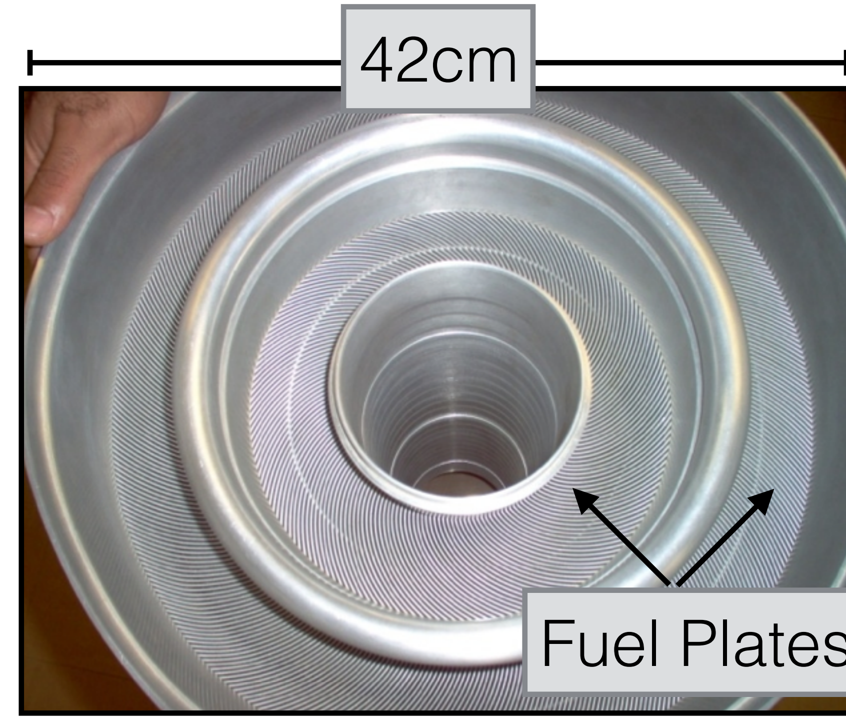
- **Phase 1:**
  - Sterile neutrino search, cover best fit region at 4σ in 1 year
  - World-leading ^{235}U spectrum with 100k events/year
- **Phase 2:** World-leading short baseline sensitivity

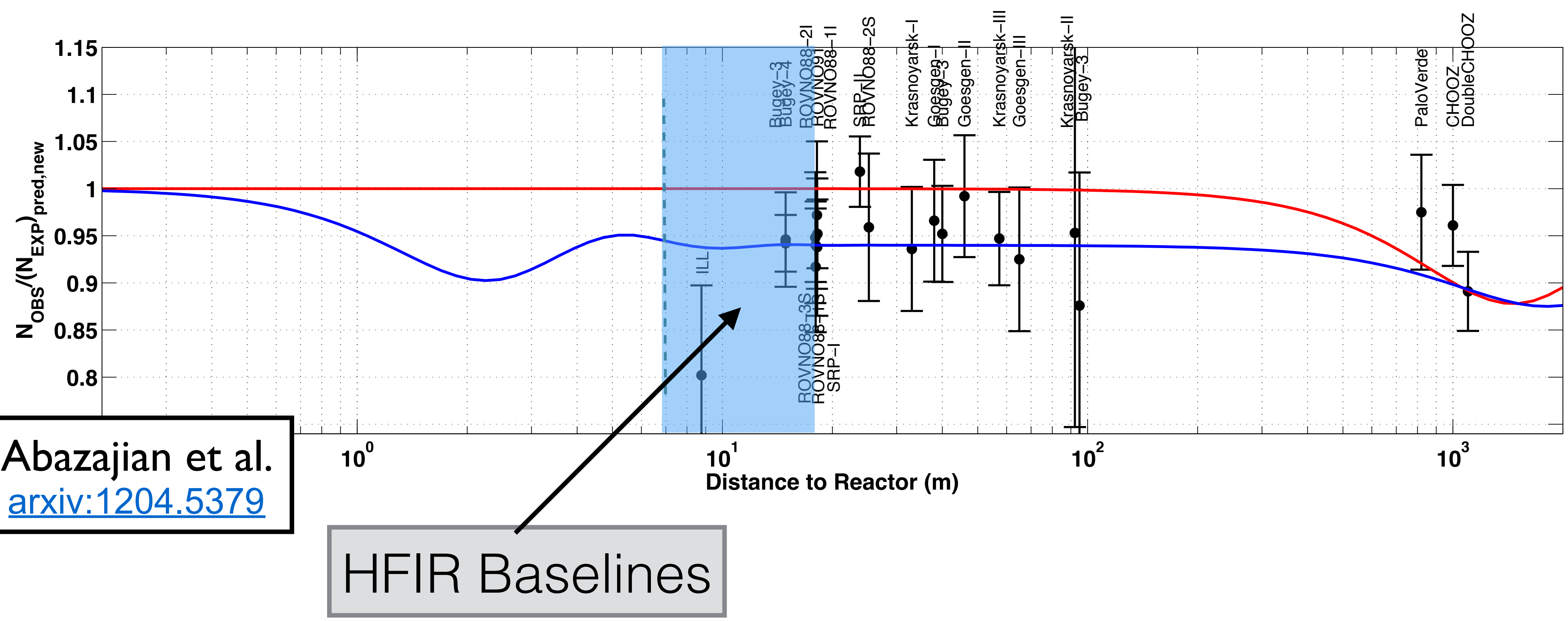
Challenges:

- Minimal overburden, cosmogenic backgrounds
- Reactor-related backgrounds
  - High energy (≲10MeV) gammas

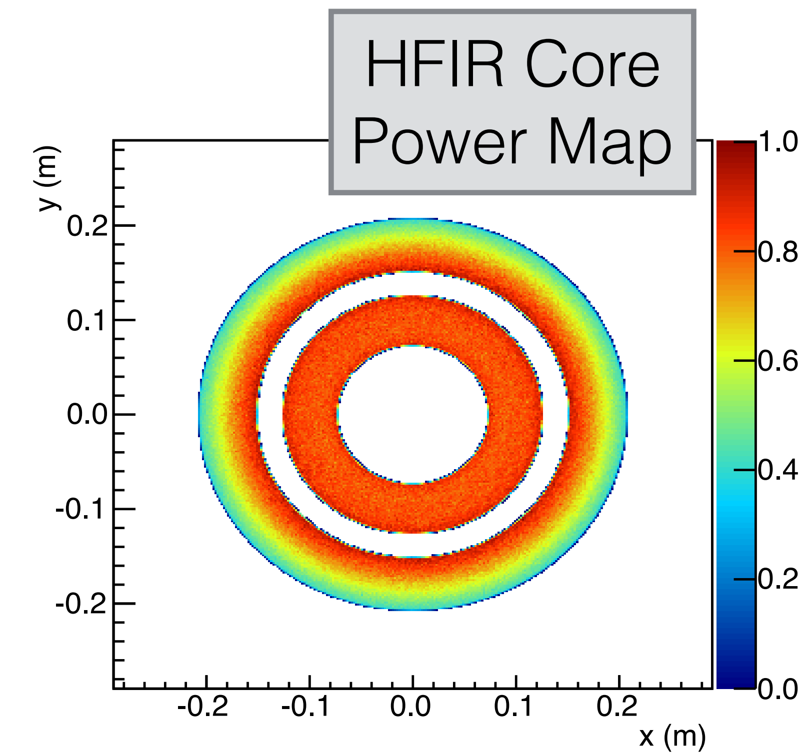
High Flux Isotope Reactor

- High Flux Isotope Reactor (HFIR) at Oak Ridge National Lab
- 85MW HEU (>94% of $\overline{\nu}_e$ flux from ^{235}U fission) compact-core reactor, 42% uptime
- PROSPECT activity for past 3 yrs
- Backgrounds well characterized
- Unique location for a short baseline experiment





Abazajian et al.
arxiv:1204.5379

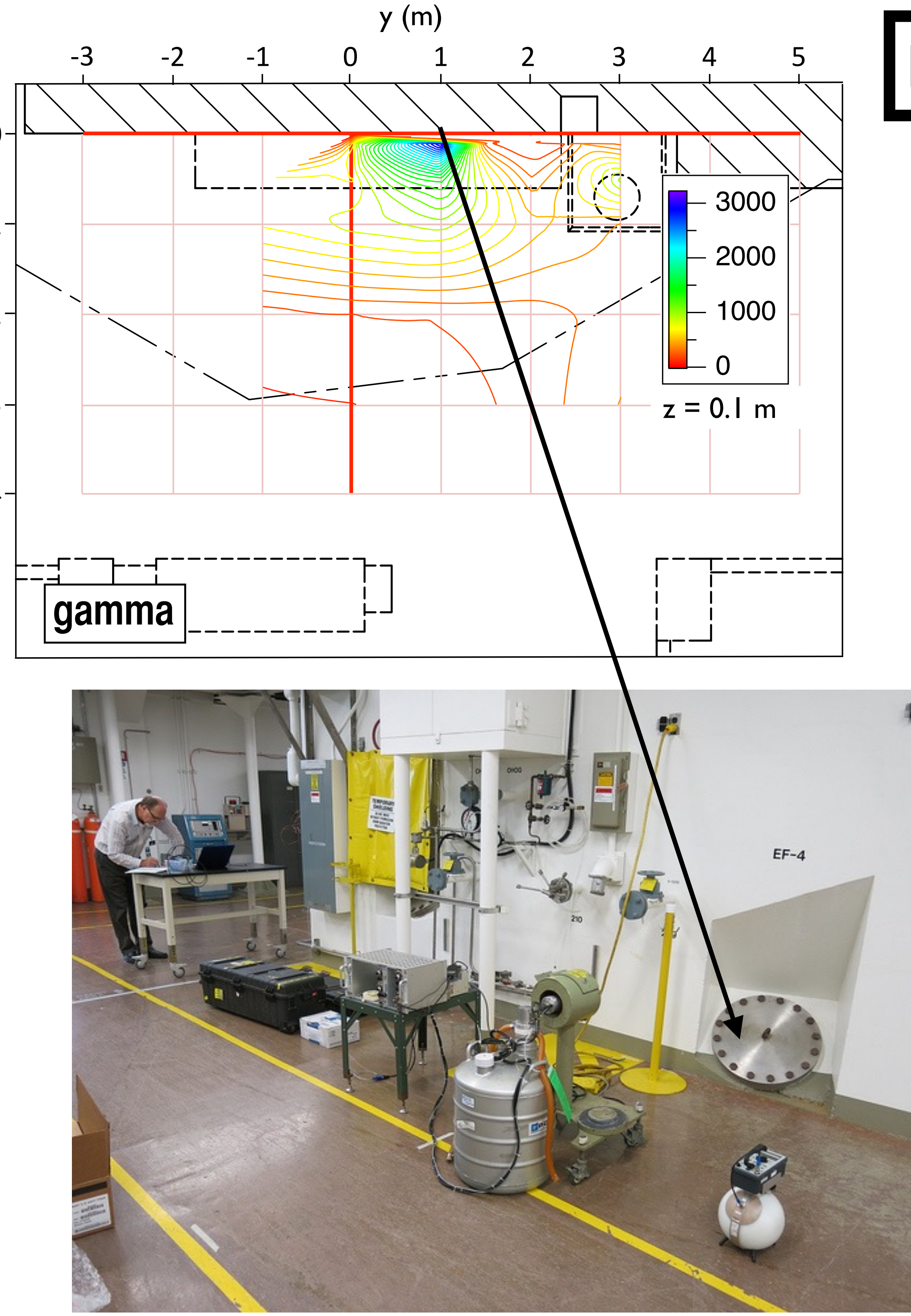


Surface Neutrino Detection

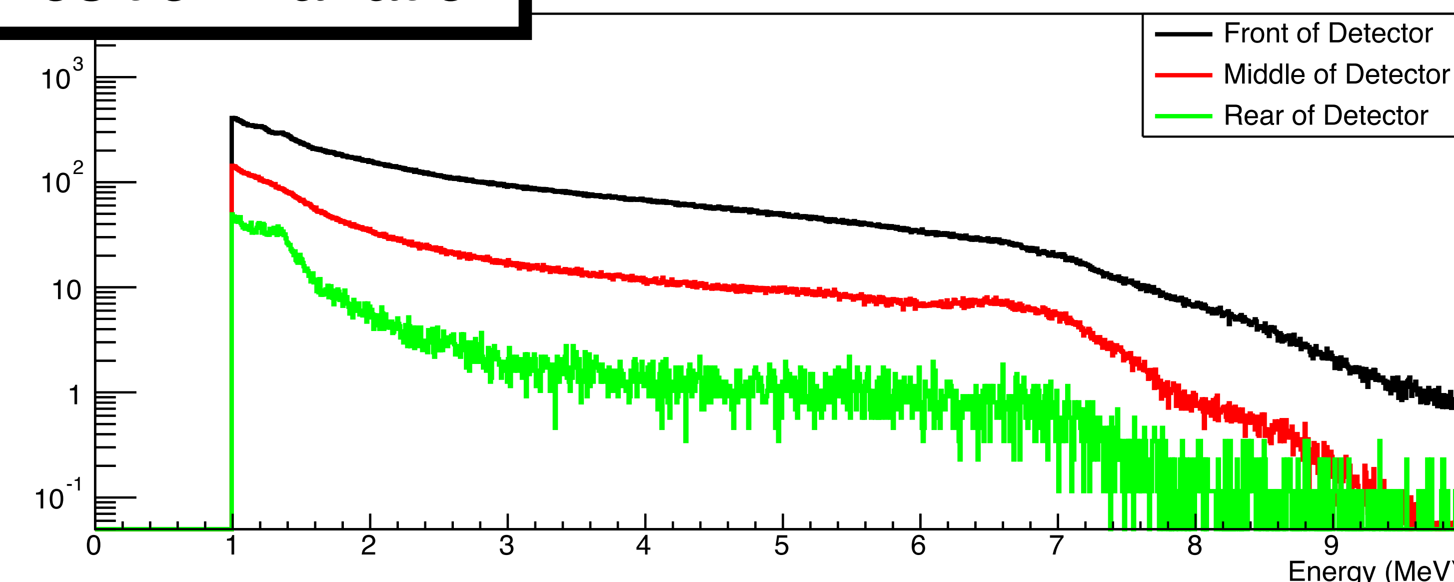
Must be very close to research reactor

- Reactor-related backgrounds (gammas and thermal n)
- Detector will have to operate at the surface (or close to it)
- *Cosmic-rays are problematic*

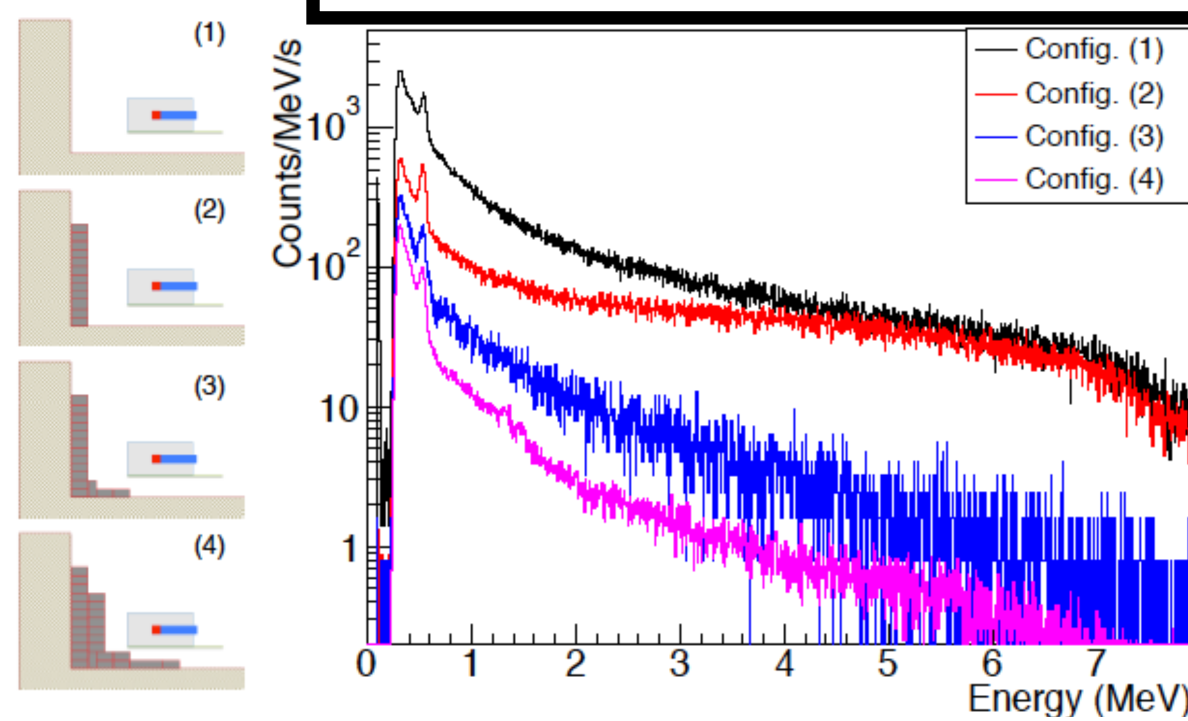
Reactor Backgrounds



Position Variation

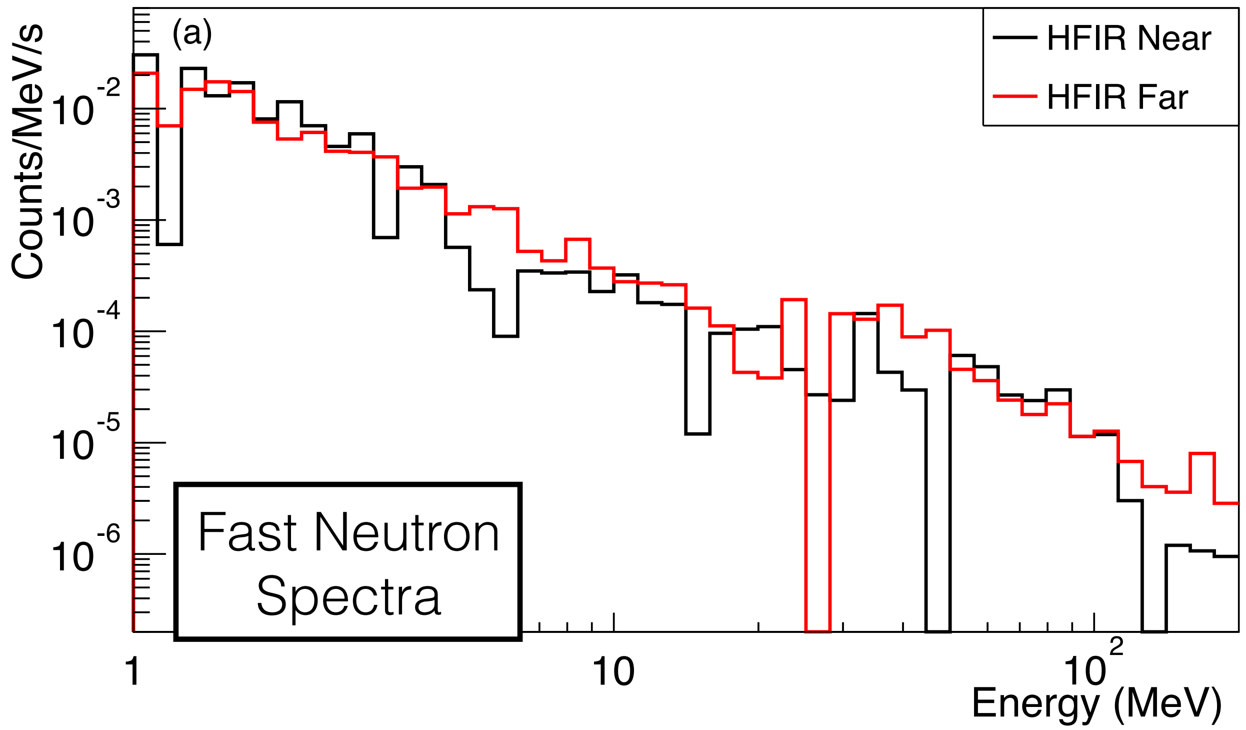


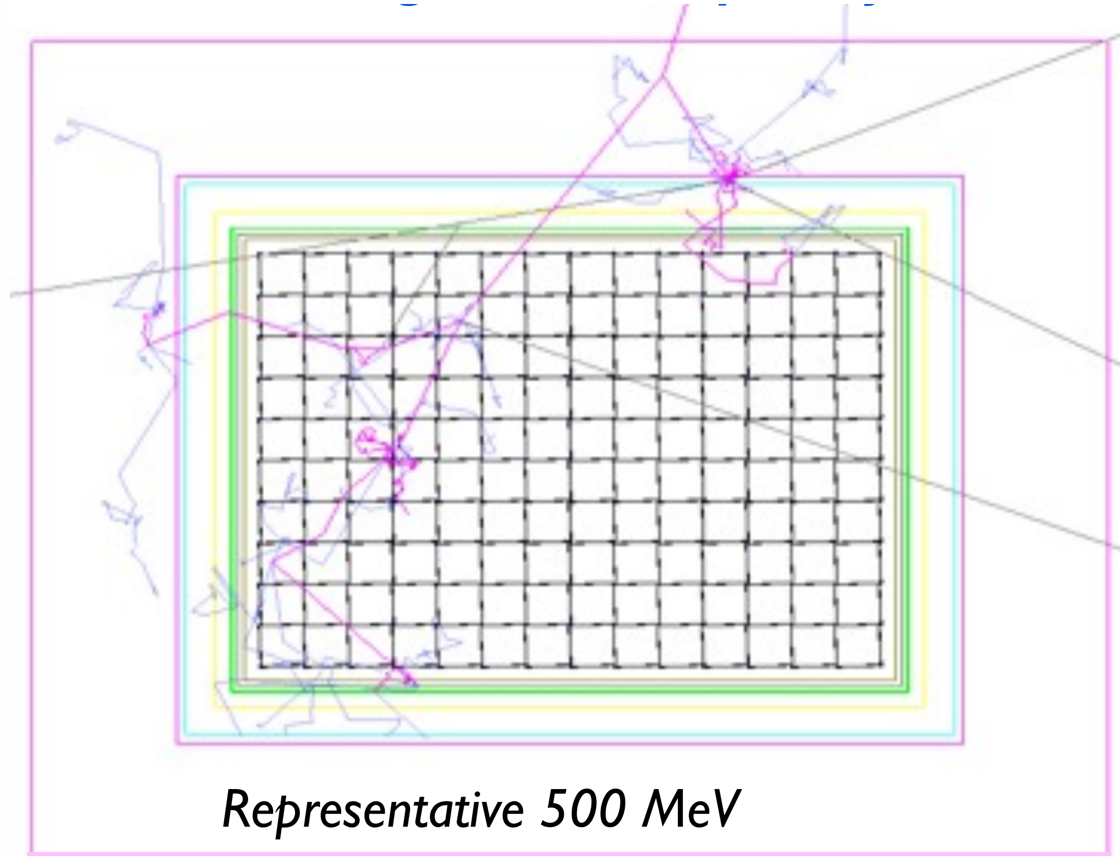
Rate Variation with Shielding



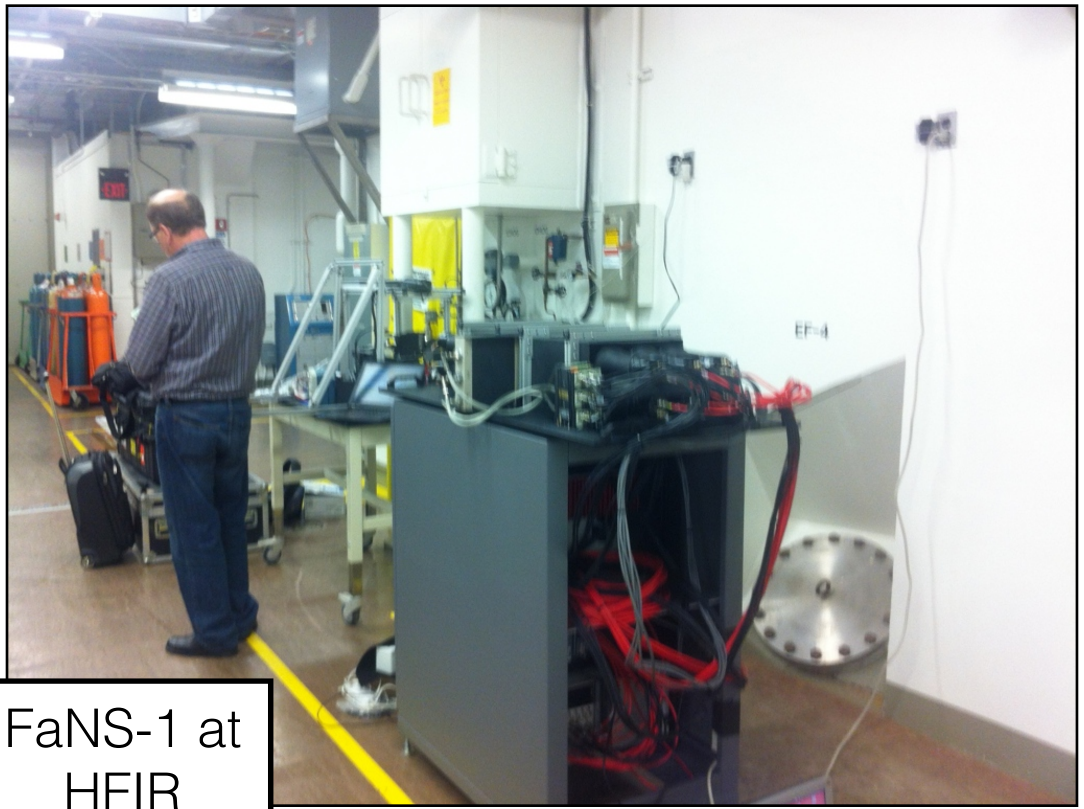
Targeted shielding effectively reduced gamma backgrounds

Cosmogenic Backgrounds





Representative 500 MeV



FaNS-1 at HFIR

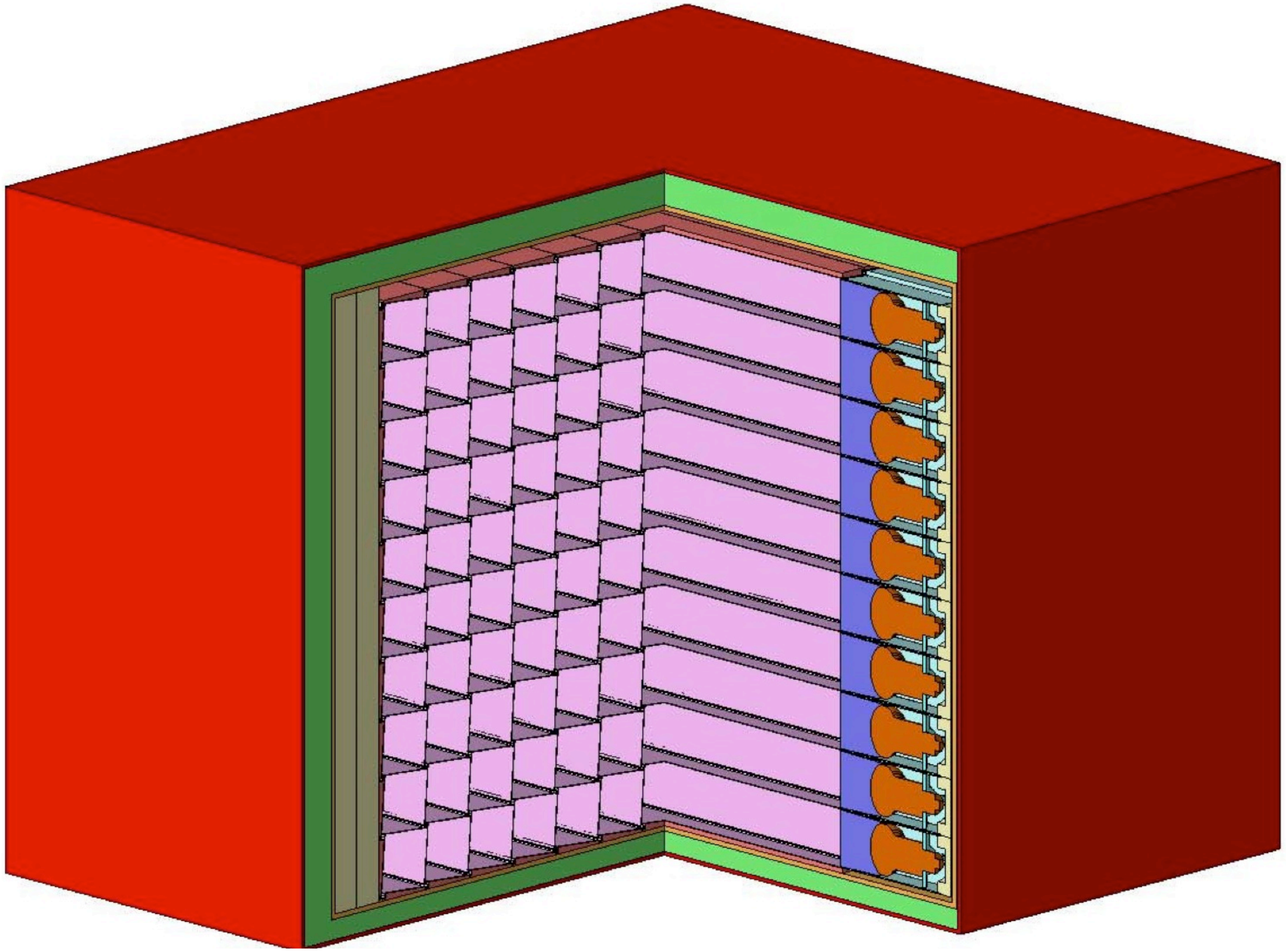
- <10MeV neutrons are effectively shielded
- >100MeV neutrons create showers of particles and many secondary neutrons
- IBD-like backgrounds stem mainly from fast neutron interactions

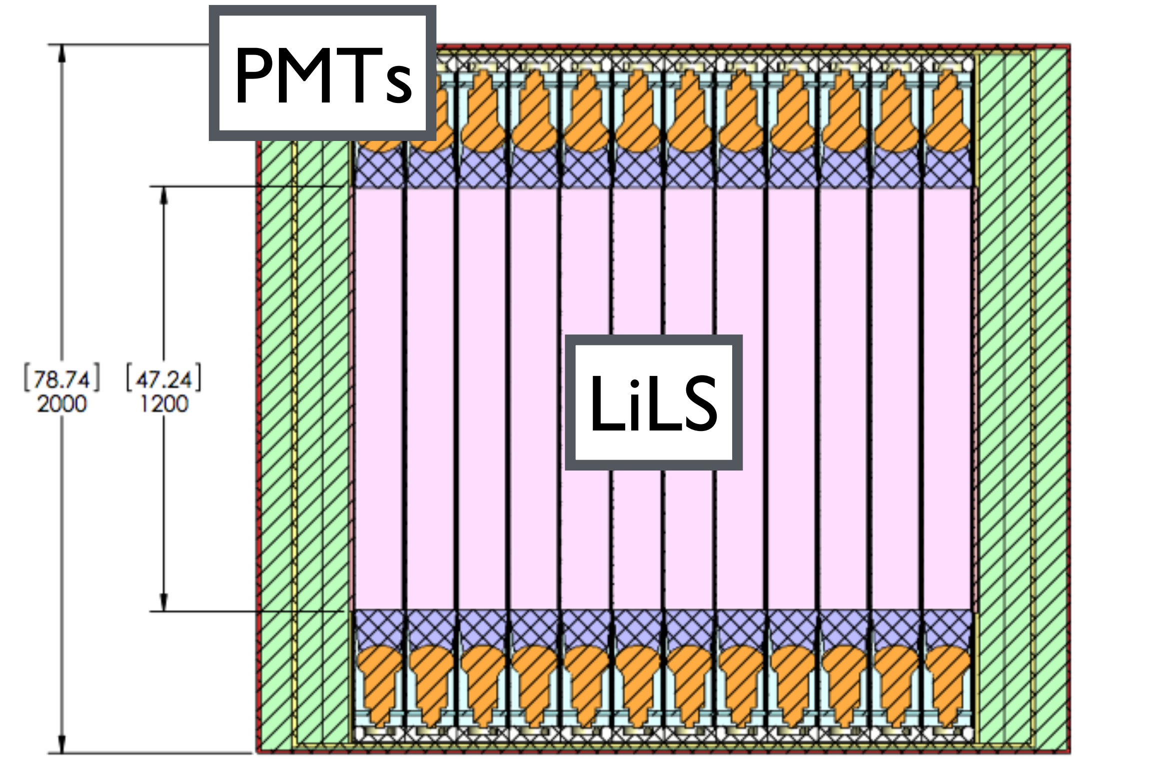
Surface Neutrino Detection

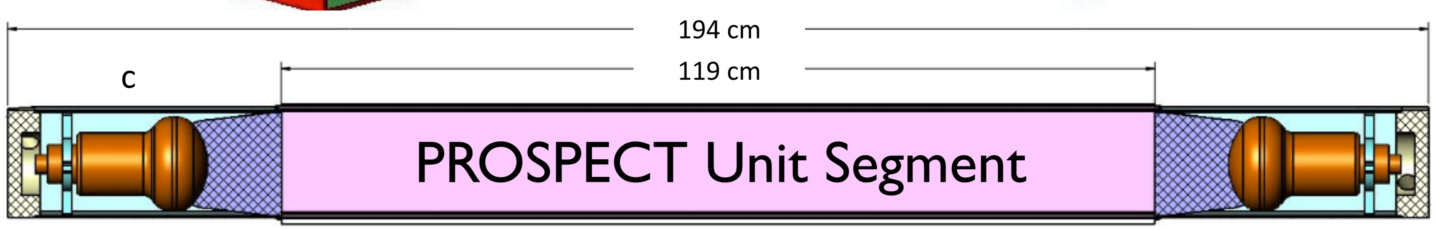
Three-pronged effort to address these backgrounds:

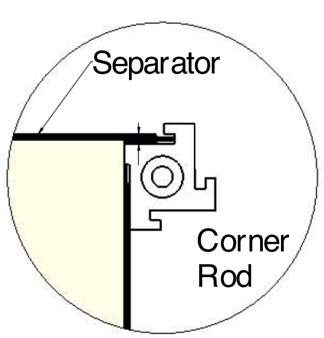
1. New detector design
2. New liquid scintillator
3. New shielding design

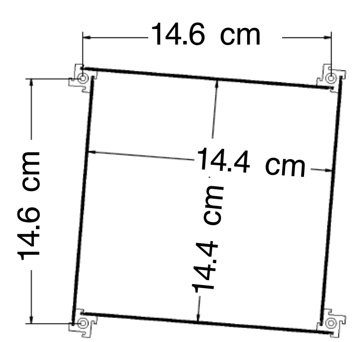
Segmented Antineutrino Detector





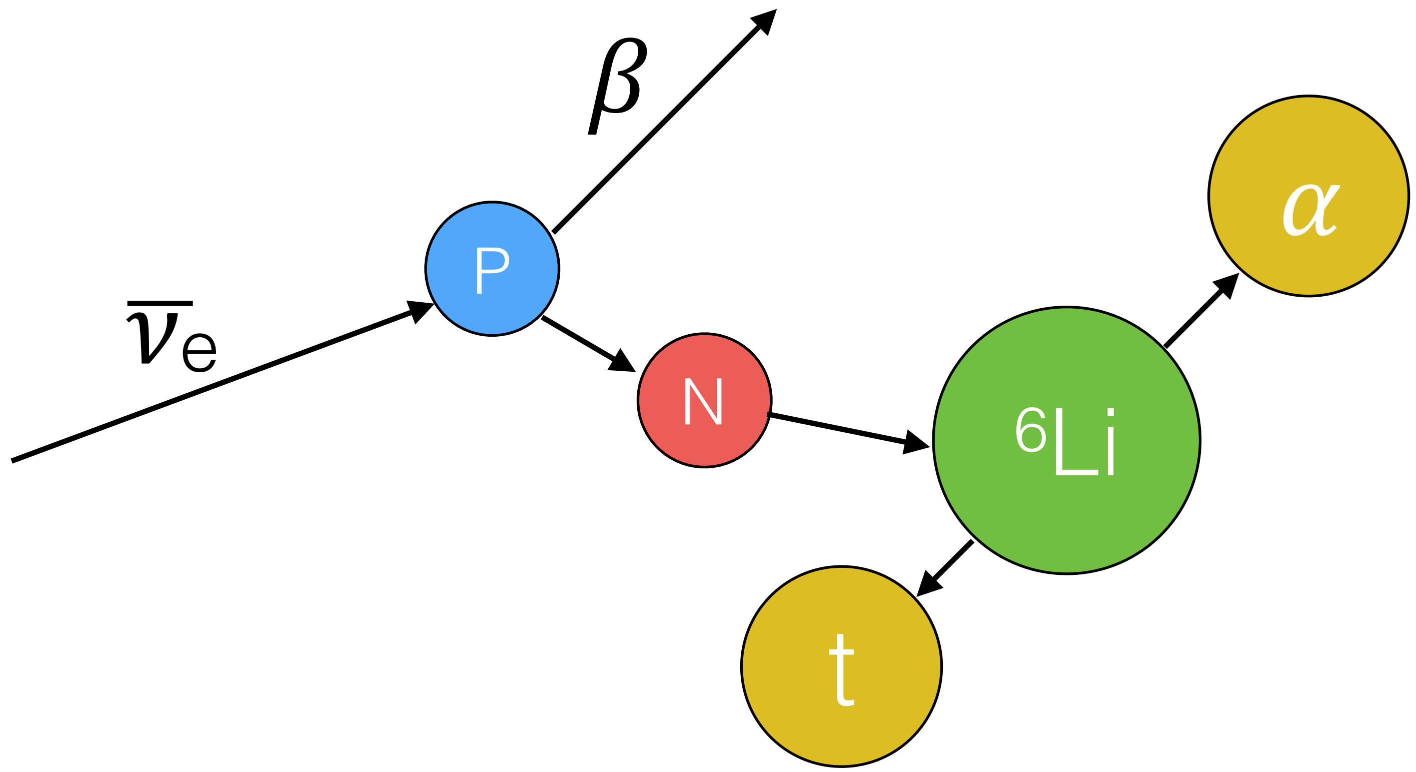






- 3ton lithium-loaded liquid scintillator (^{6}LiLS) detector
- 120 optical segments
  - 15x15x119cm^3, ~25 liters each
  - **Identify multiple particle interactions, reject showers**
- Double-ended PMT readout
- Access for calibration sources between every cell

IBD Detection with ^{6}LiLS



Prompt signal: 1-10 MeV positron from inverse beta decay (IBD)

Delay signal: ~0.6 MeV signal from neutron capture on ^{6}Li **with PSD signature**

Pulse-shape Discrimination (PSD) Signatures

Inverse Beta Decay
γ-like prompt, n-like delay

Fast Neutron
n-like ~~prompt, n-like~~ delay

Accidental Gammas
γ-like ~~prompt, γ-like~~ delay

Coincidence Signature of event:
e-like prompt signal, followed by a ~50μs delayed neutron capture

Coincidence + PSD allows rejection of vast majority of backgrounds

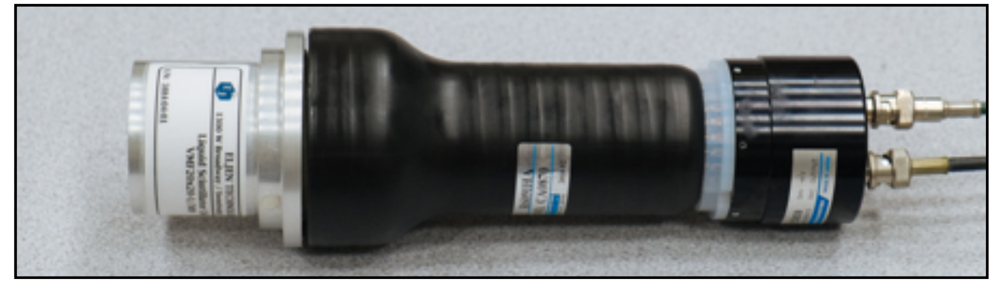
^{6}Li-loaded Liquid Scintillator

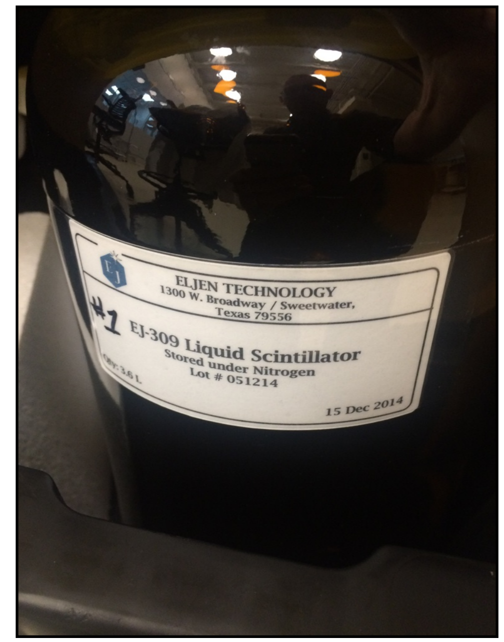
LiLS Requirements:

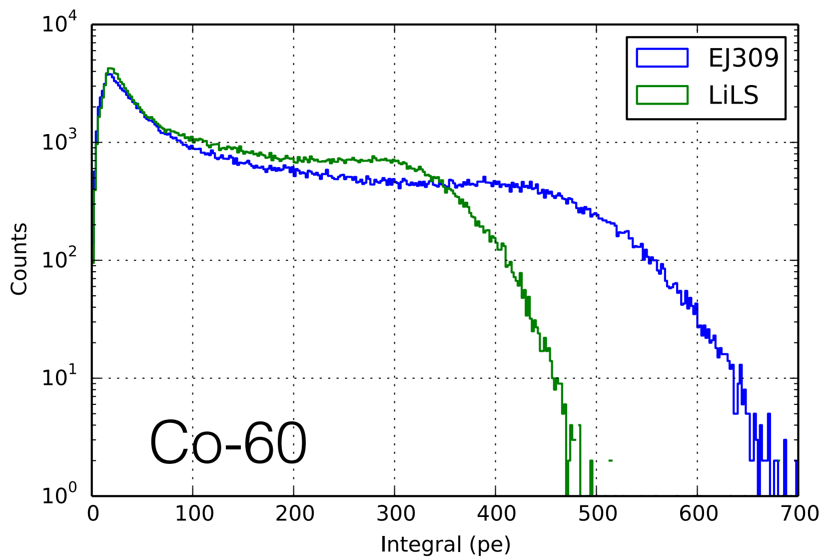
- High light yield (>6000ph/MeV) for energy resolution
- Excellent pulse-shape discrimination (PSD)
- Non-toxic, high flashpoint
- Stable and affordable

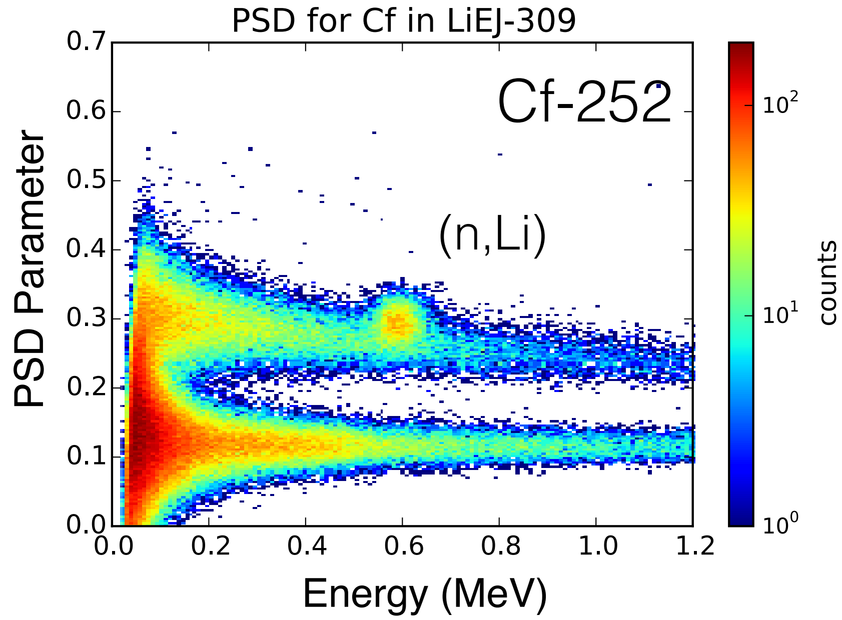
LiLS based on EJ-309 meets all requirements

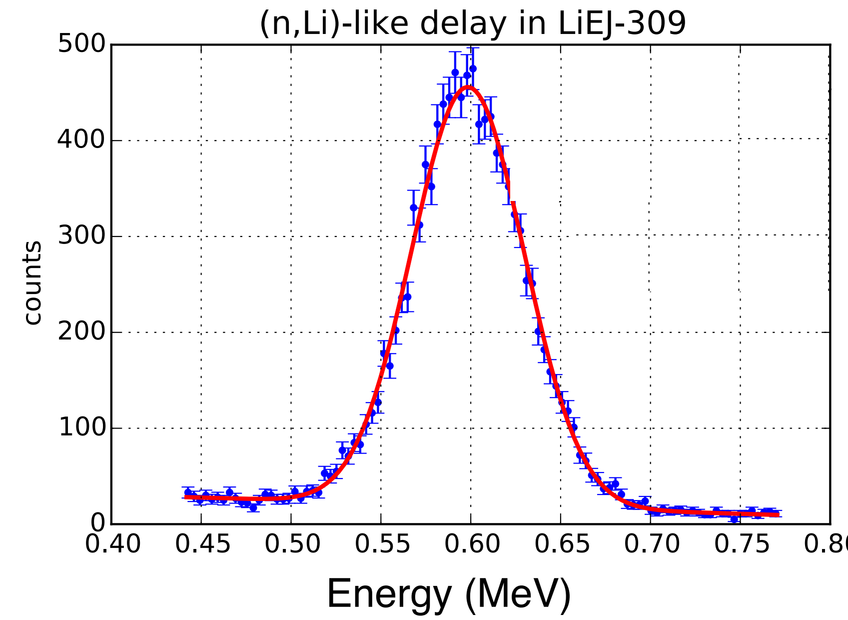
- 8200ph/MeV, excellent PSD
- **Safe to operate at a reactor**





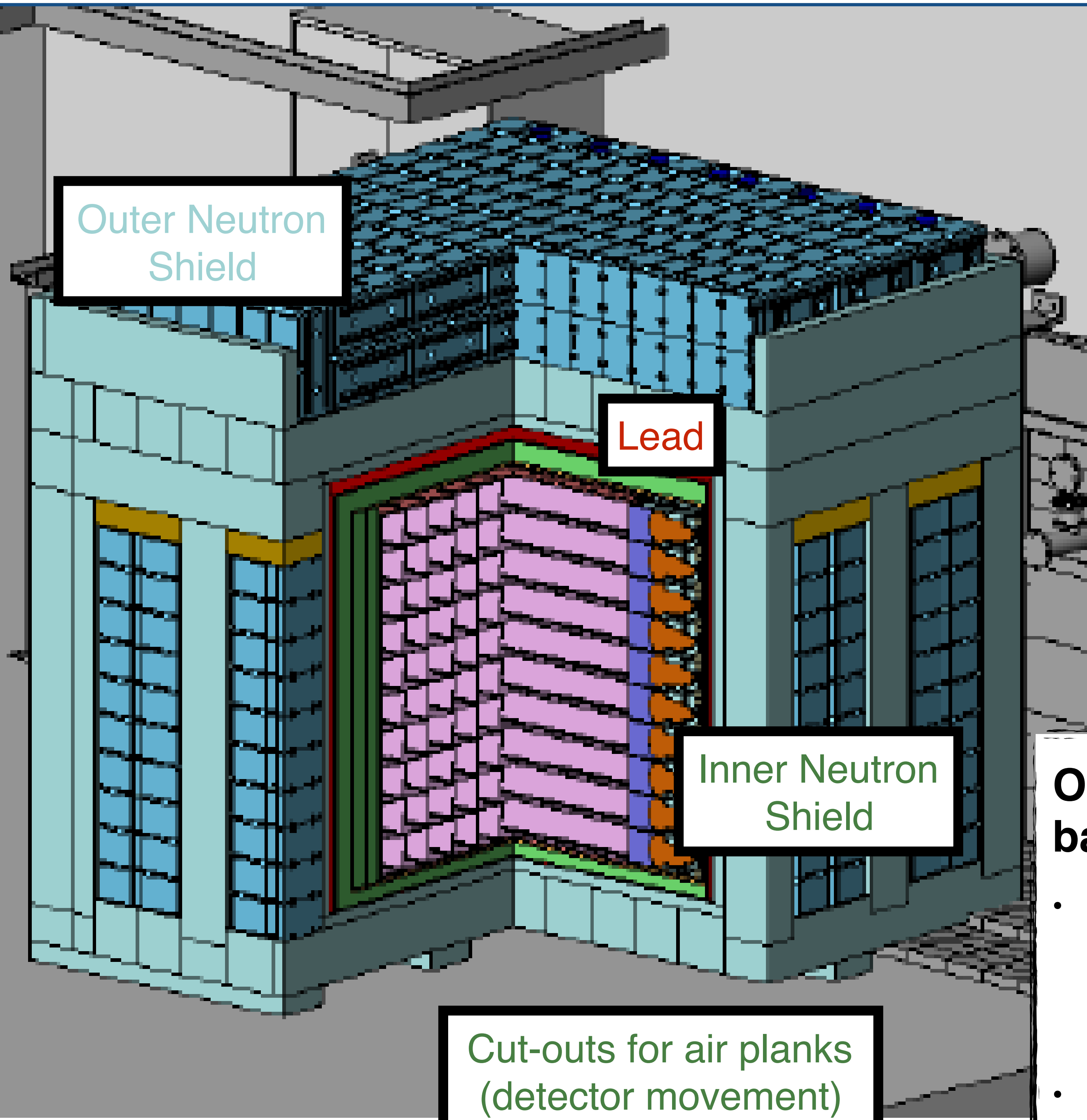


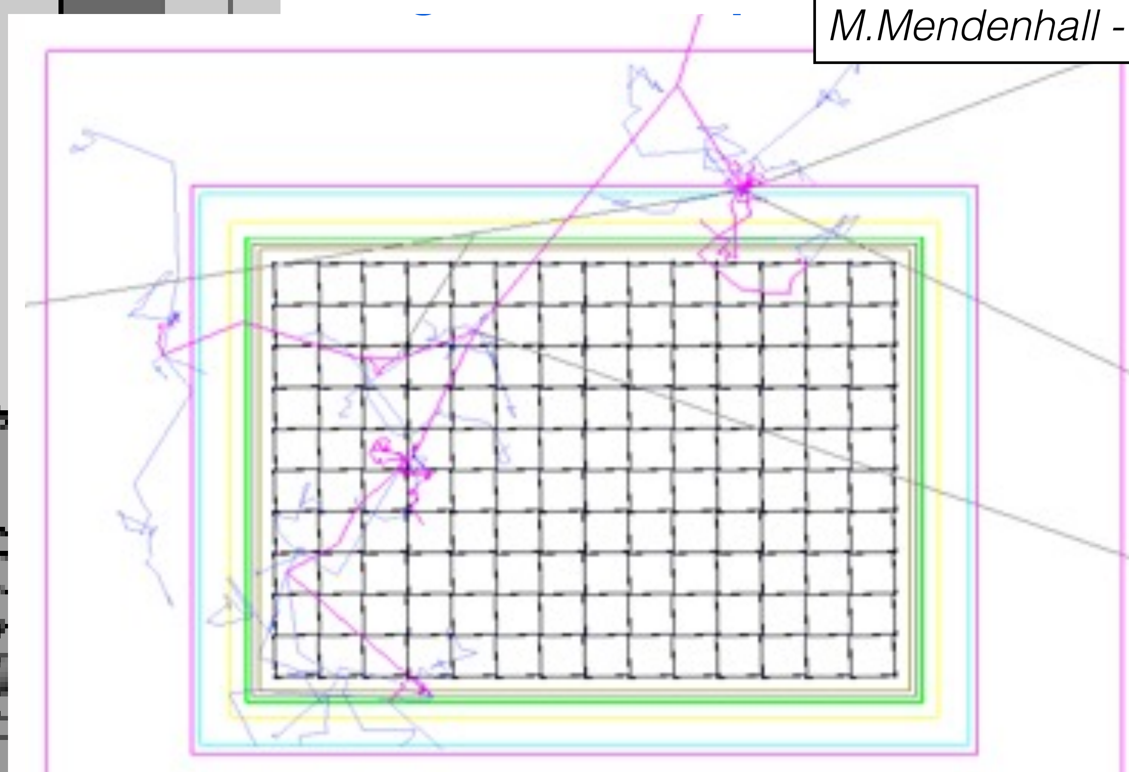




developed novel LiLS with excellent light yield, PSD, and neutron capture capabilities

Novel Shielding Design



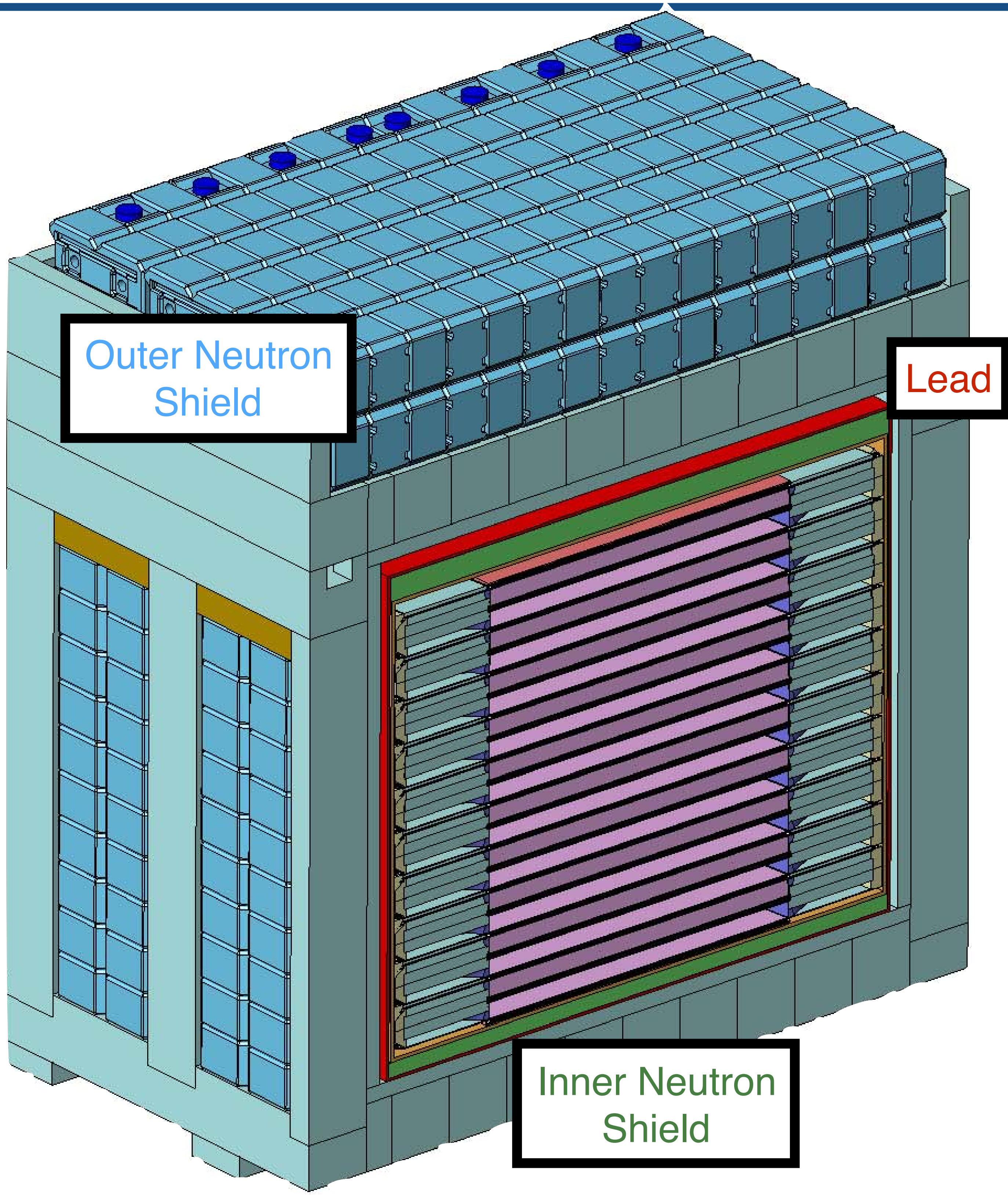


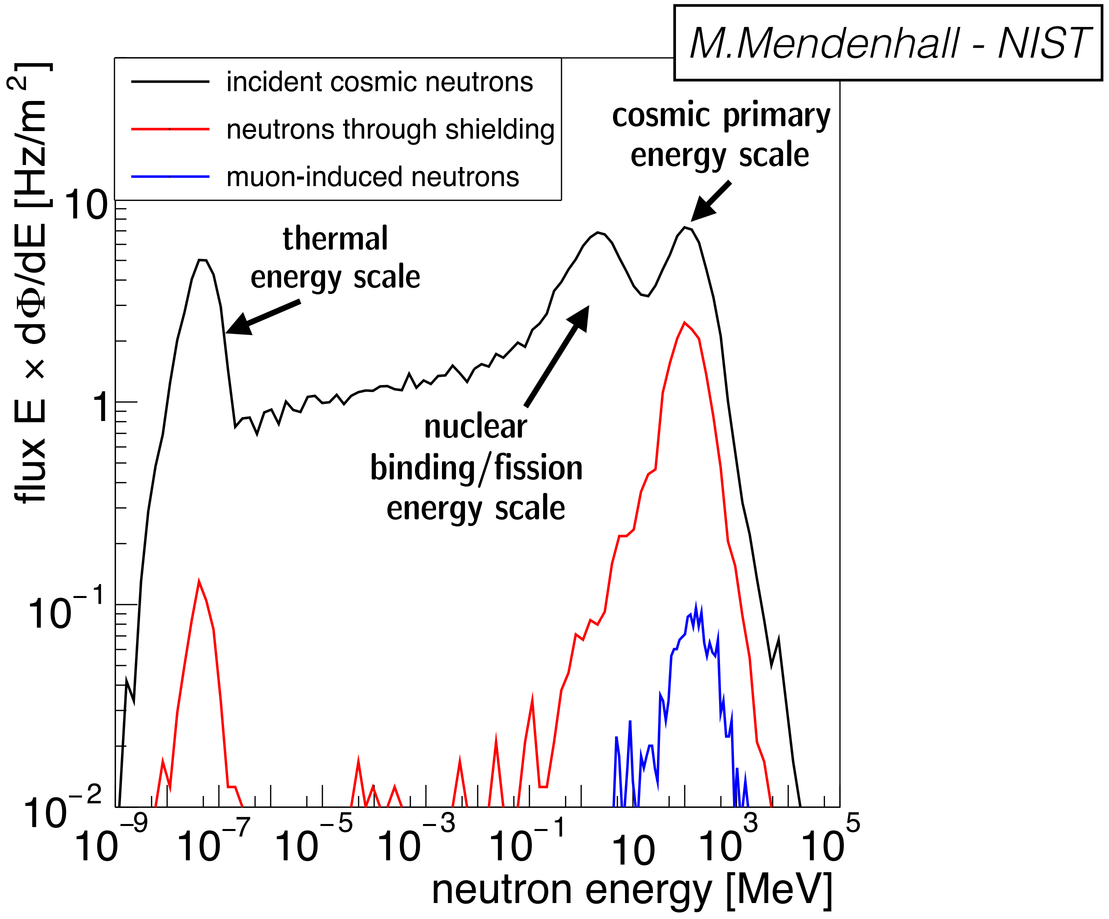
Representative 500MeV Neutron Primary

Optimize space, weight, and total background suppression

- Main problem is ~100MeV neutrons
  - create majority of IBD-like backgrounds (gamma-like prompt, neutron capture)
- Neutron spallation on high-Z shielding increases backgrounds
- *Need neutron shielding inside lead shielding*

Novel Shielding Design





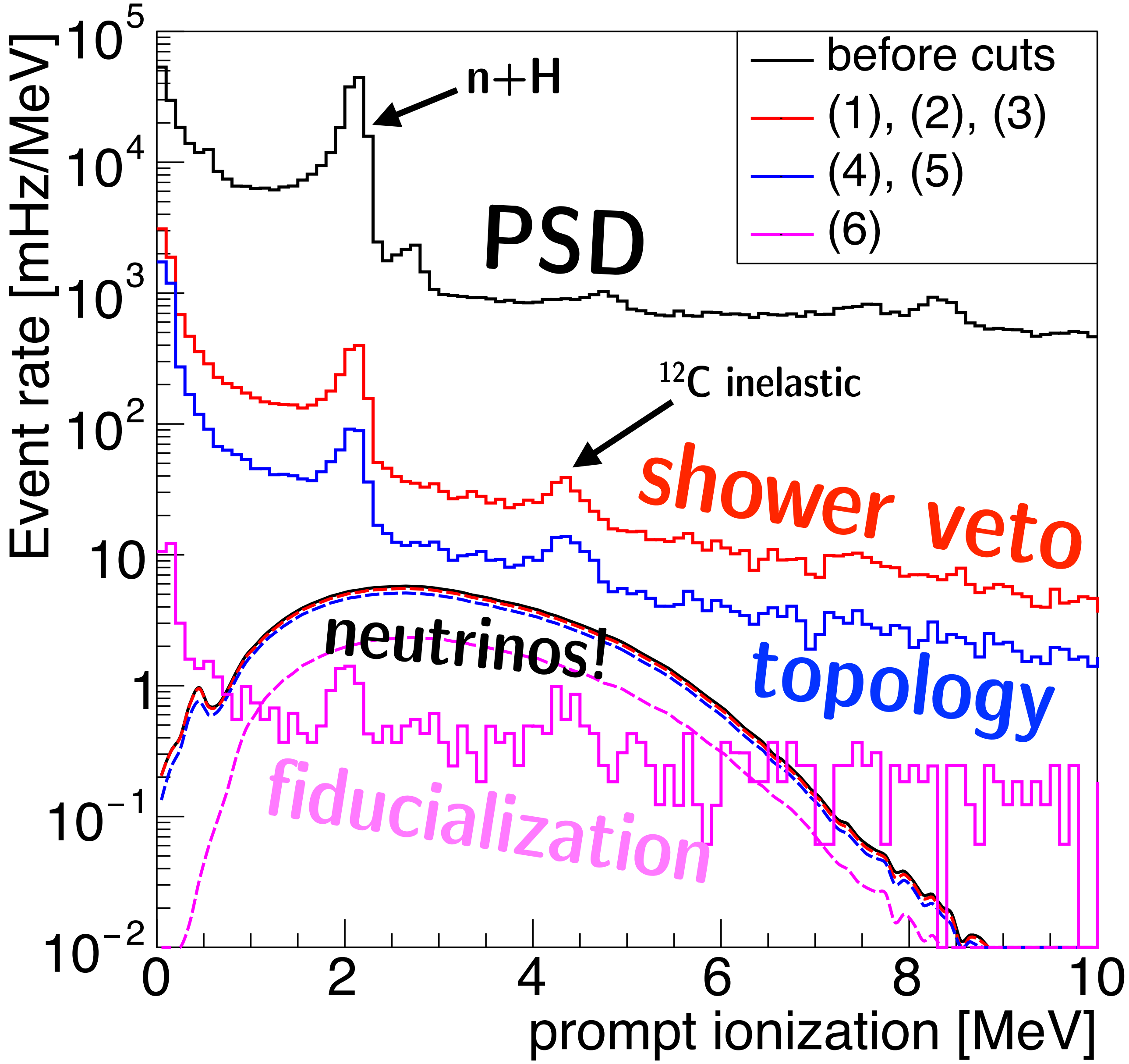
Optimize space, weight, and total background suppression

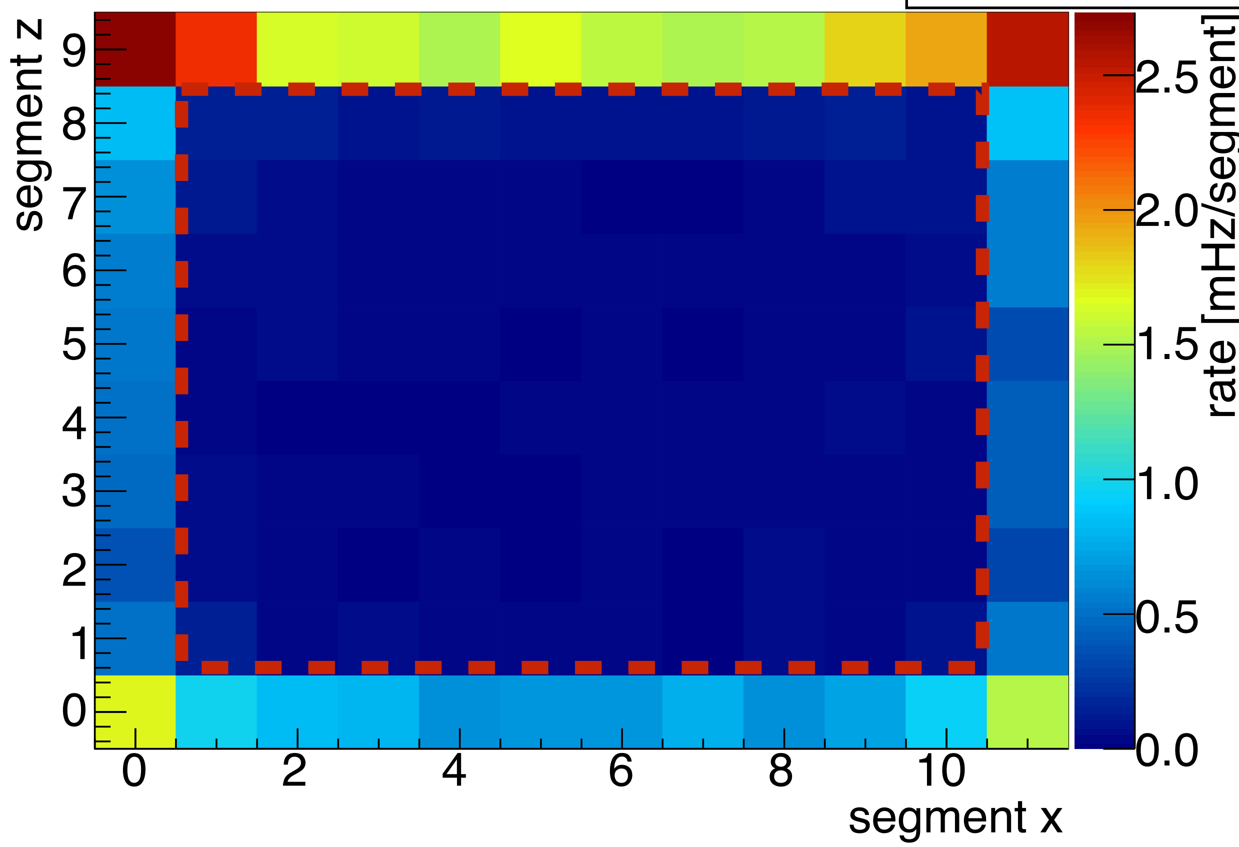
- Main problem is ~100MeV neutrons
  - create majority of IBD-like backgrounds (gamma-like prompt, neutron capture)
- Neutron spallation on high-Z shielding increases backgrounds
- *Need neutron shielding inside lead shielding*

BG Rejection via Detector Design

M.Mendenhall - NIST

Neutron coincident events





Background reduction steps:

- Efficient PSD and neutron tagging
- Identification of multiple particle interactions
- **Fiducialization**

Active suppression of >3 orders of magnitude

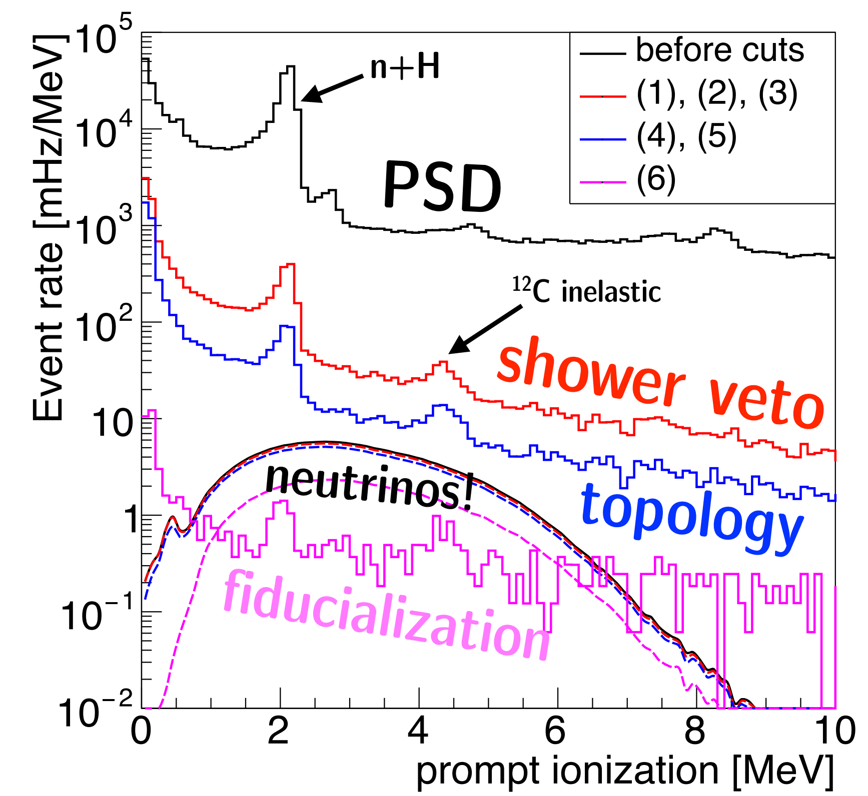
PROSPECT Signal and Background

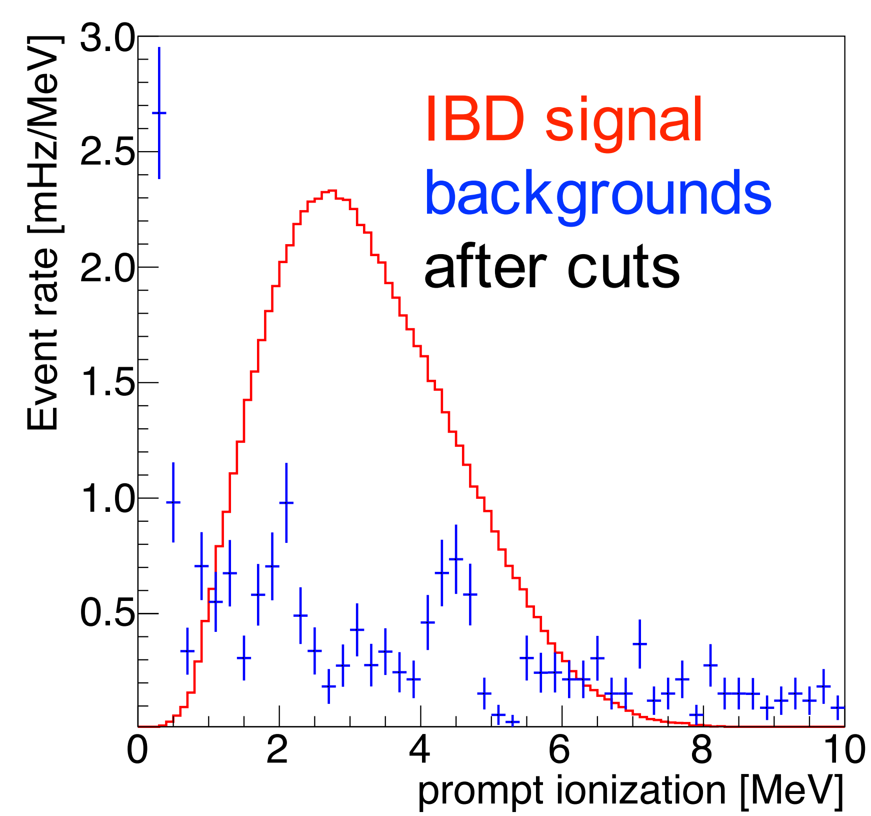
- Signal (dashed) and background (solid) prompt spectra are shown through selection cuts
- S/B better than 1:1 is predicted.
- Rate and shape of the residual IBD-like background can be measured with high precision during reactor off periods.

Cuts	IBD signal
Exposure	*Daily*
PSD	1630
Time (1, 2, 3)	1570
Spatial (4, 5)	1440
Fiducial (6)	660

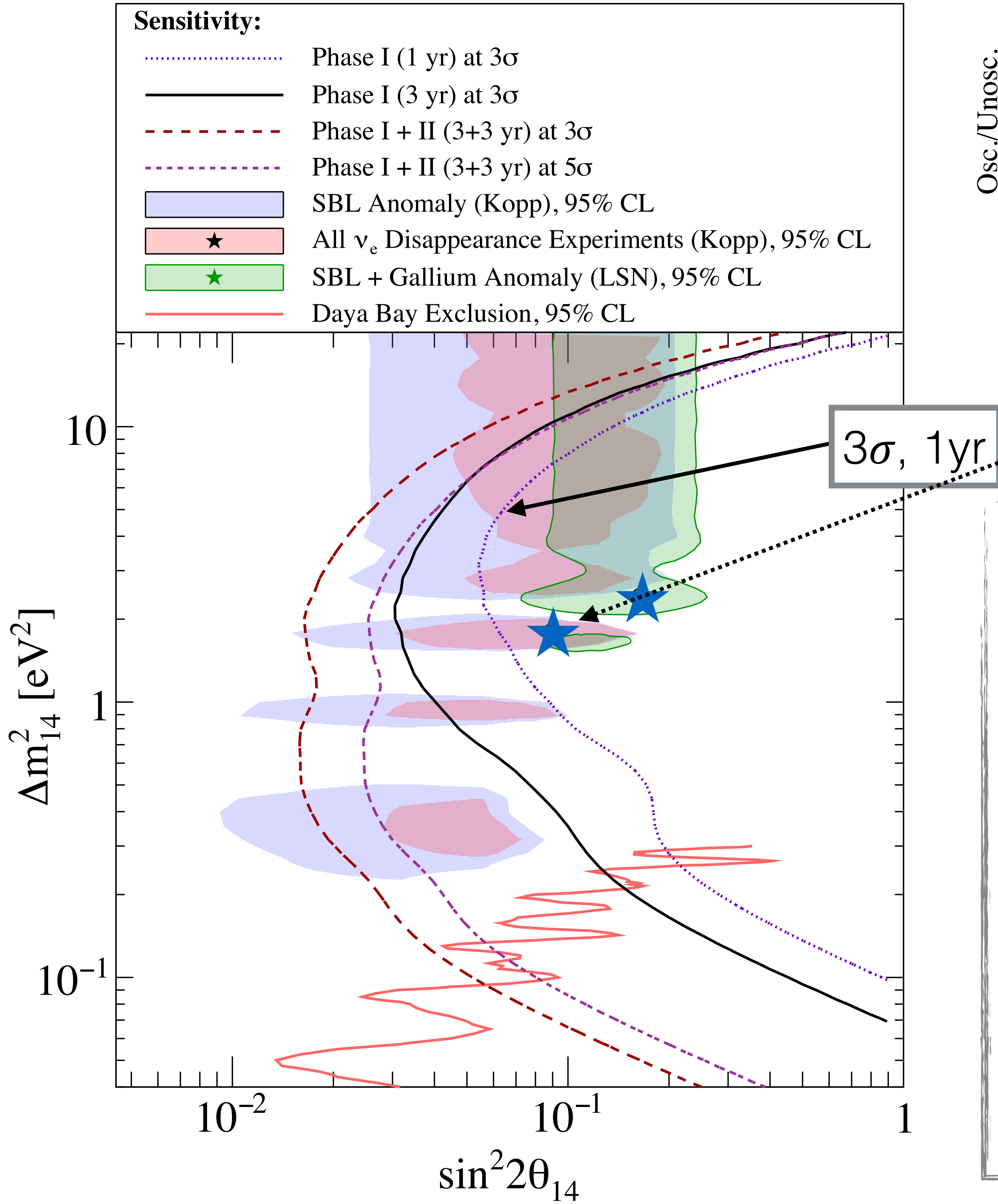
Cosmic BG
Daily
2.1e6
3.4e4
9900
250

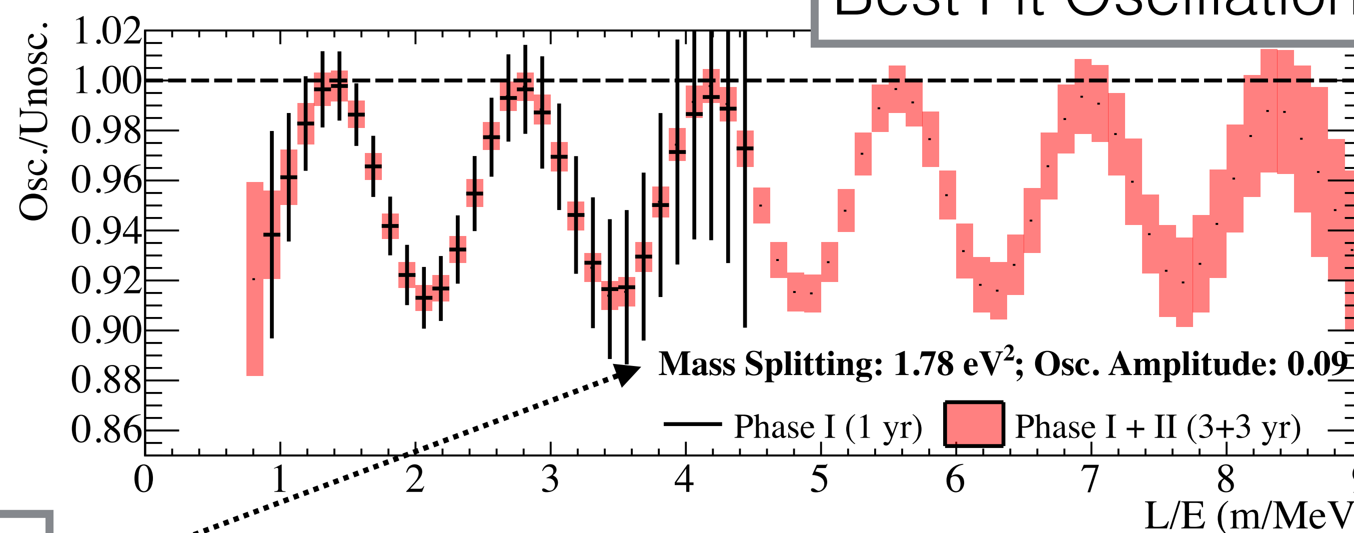
Simulated event rates (0.8 ≤ E ≤ 7.2 MeV) after applying background rejection cuts





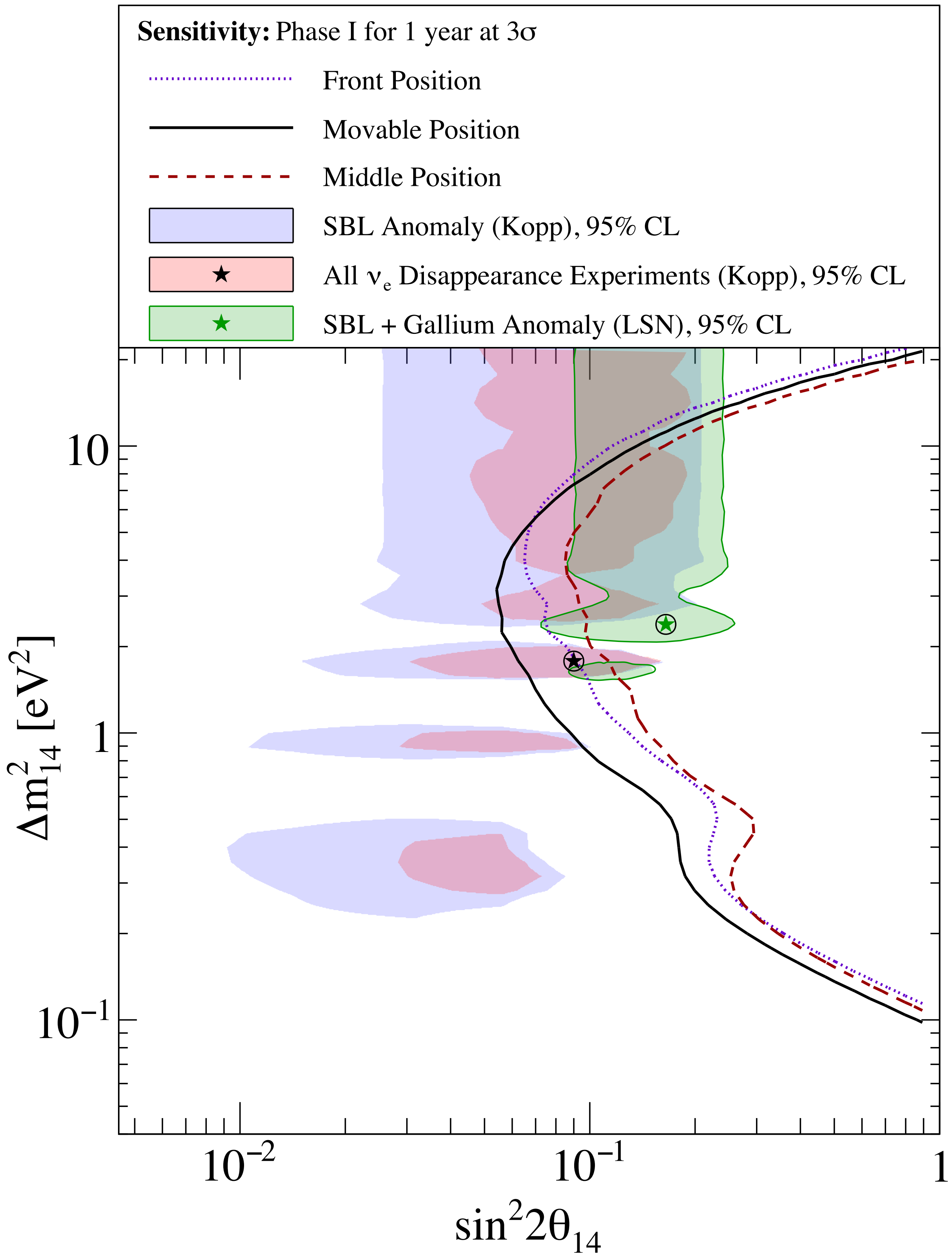
Short Baseline Oscillation Search

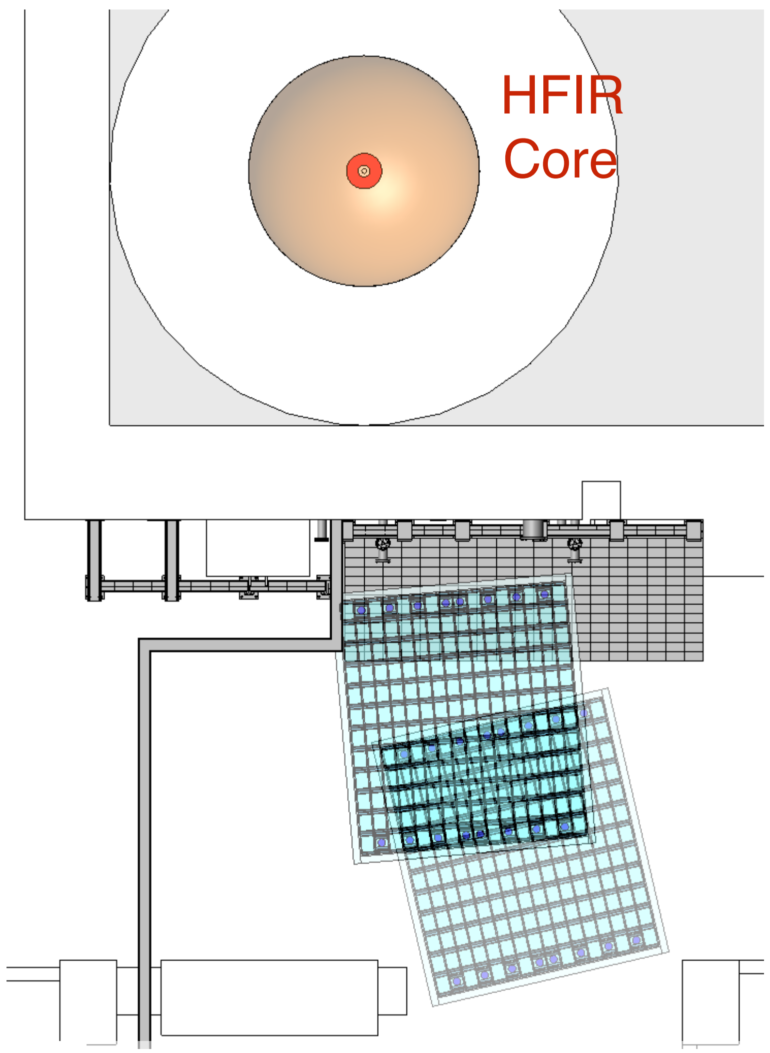




- Segmented detector designed for oscillation search
  - Each cell is a separate "detector"
  - Oscillatory L/E between segments limits uncertainties from reactor
- *True oscillometry needed for confirmation of sterile neutrinos*
- **Probe best-fit region at >3σ in 1 year**

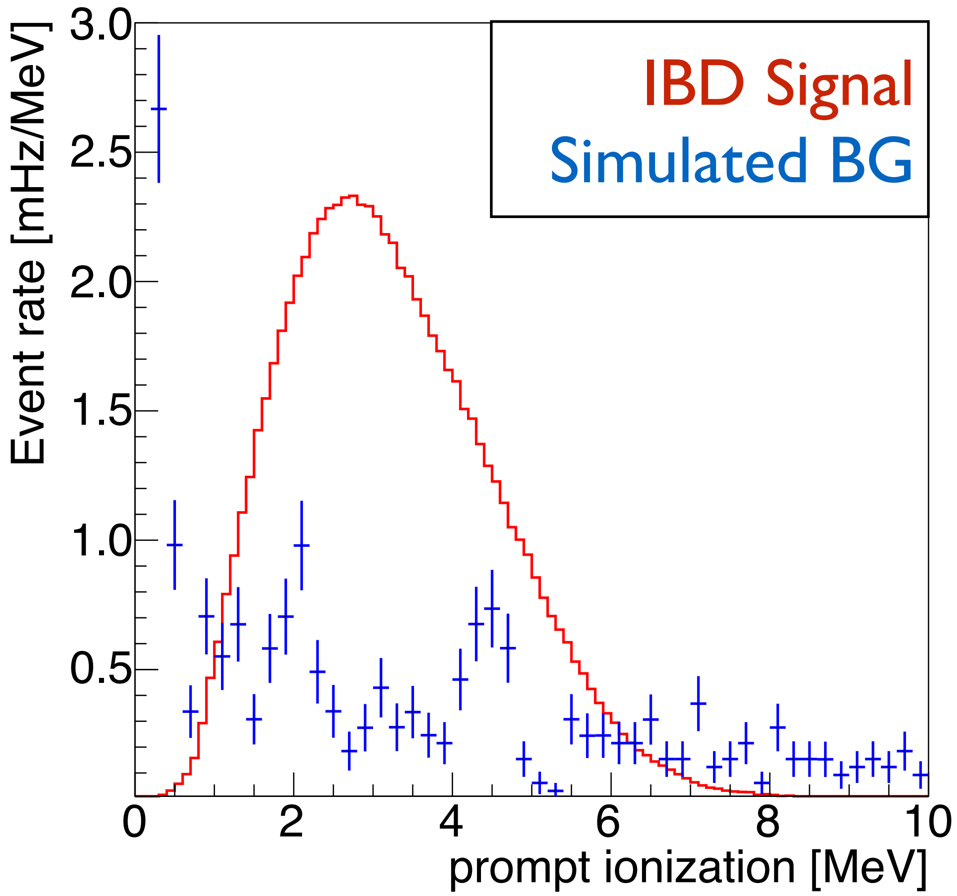
A Movable Detector

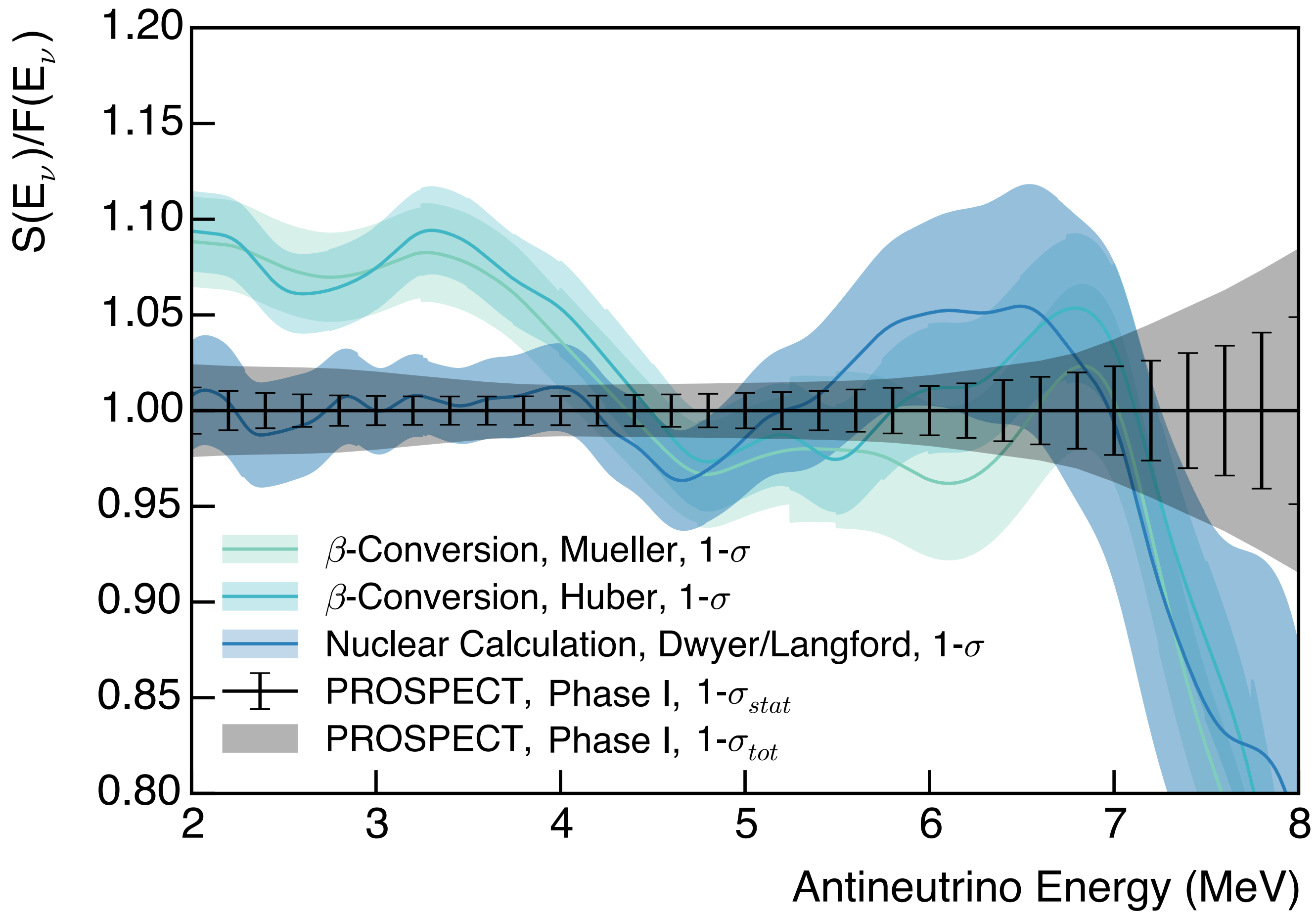




- AD-1 is designed to translate by 1m, almost half the detector length
- Improves the sensitivity from <3σ to greater than 4σ
- Provides powerful systematics check

^{235}U Spectrum Measurement

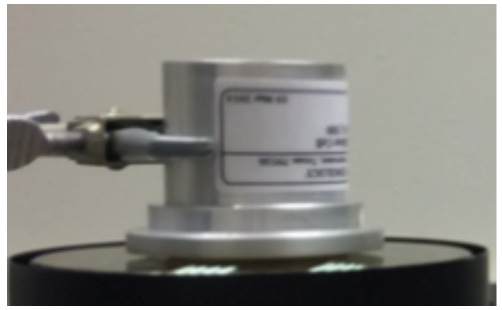




- ~700 inverse beta decays detected per day, 100k/year
- Best energy resolution of any reactor neutrino experiment (4.5%@1MeV)
- **Phase-1 precision will surpass spectral model uncertainties**
  - Directly test reactor neutrino models
  - Produce a benchmark spectrum for future reactor experiments

Phased Detector Development

PROSPECT-0.1
Aug 2014
Spring 2015



5cm
0.1liter
LS cell

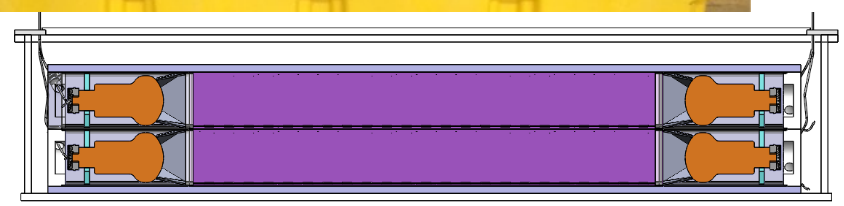
PROSPECT-2
Dec 2014
Feb 2015

12.5cm
1.7 liter
LS cell

PROSPECT-20
March 2015

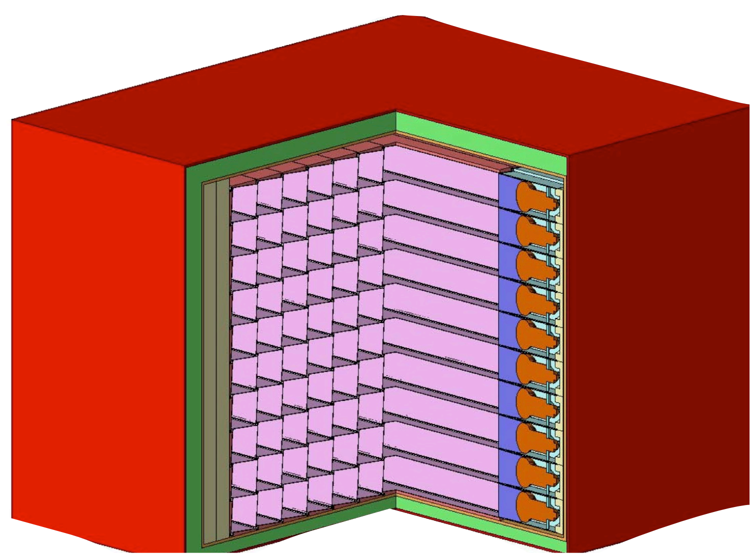
1m
23 liter
LS cell

PROSPECT-50
February 2016

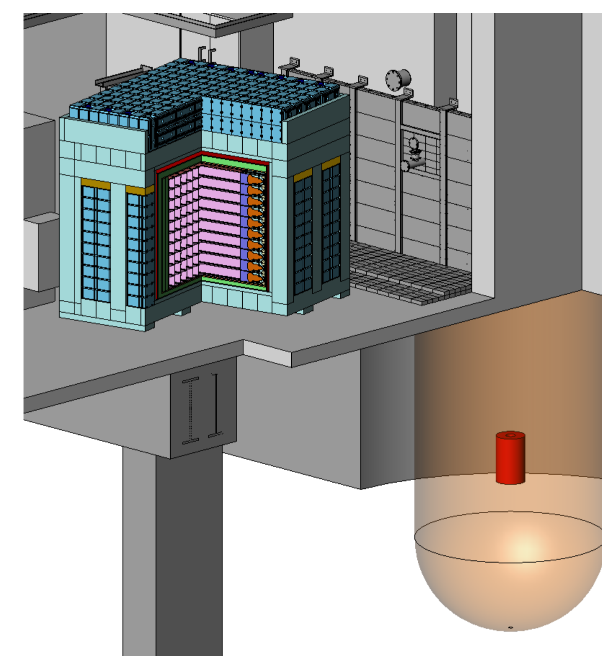


1.2m
2x25 liter
LS segments

PROSPECT
Phase I
2017*



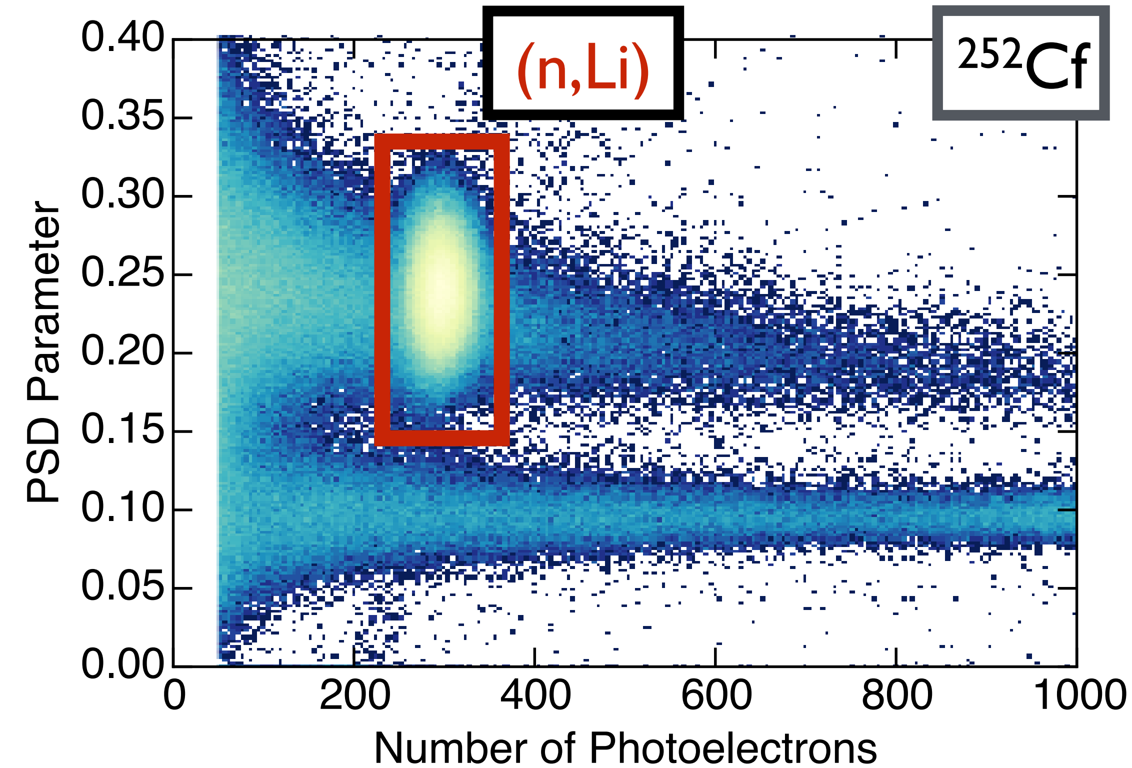
120x30 liter
LS segments
15x15x119cm

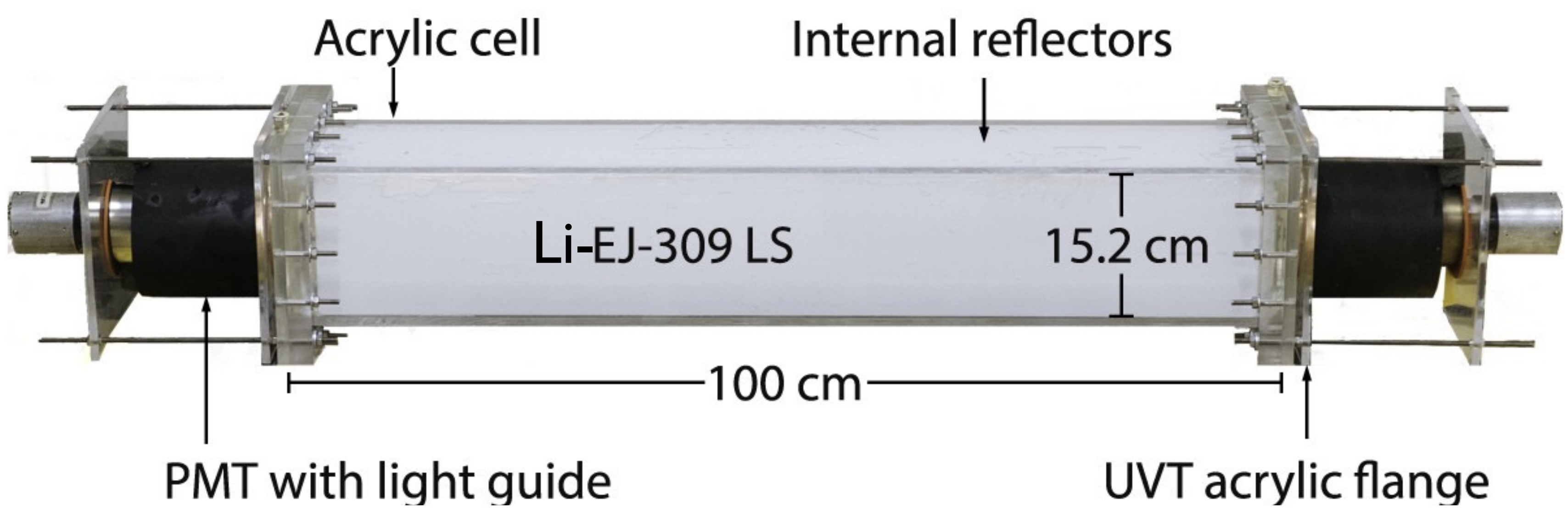


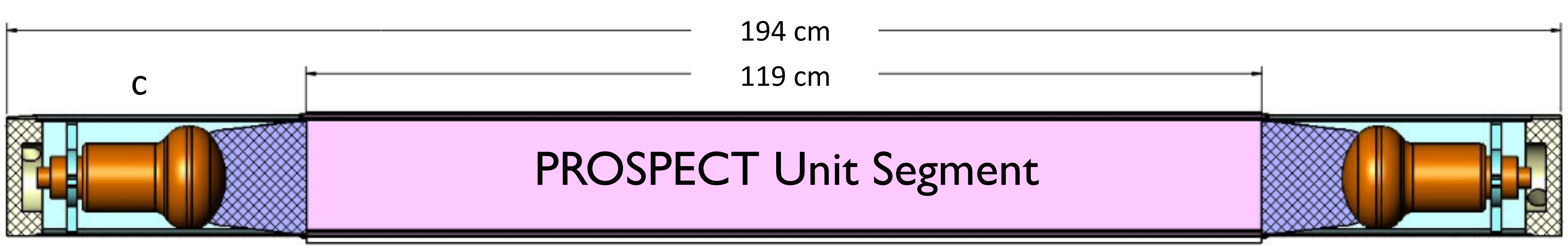
*technically driven schedule

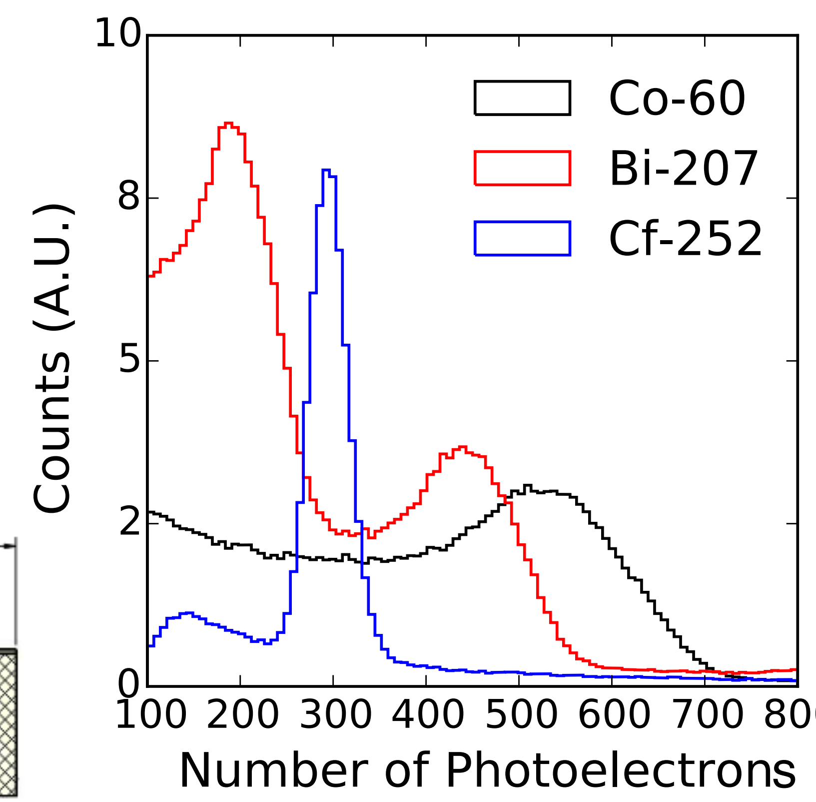
Full-scale Test Detector

- **PROSPECT-20**
  - 23L test cell of 6Li-loaded Liquid Scintillator
  - 15x15x100cm^3 detector
- Measured Light collection: 530PE/MeV
  - **4.5%@1MeV energy resolution**
- Measured PSD Figure of Merit: 1.4 at (n,Li) capture
  - **>99.9% background rejection**
- Double-ended readout
  - uniform light collection and position reconstruction



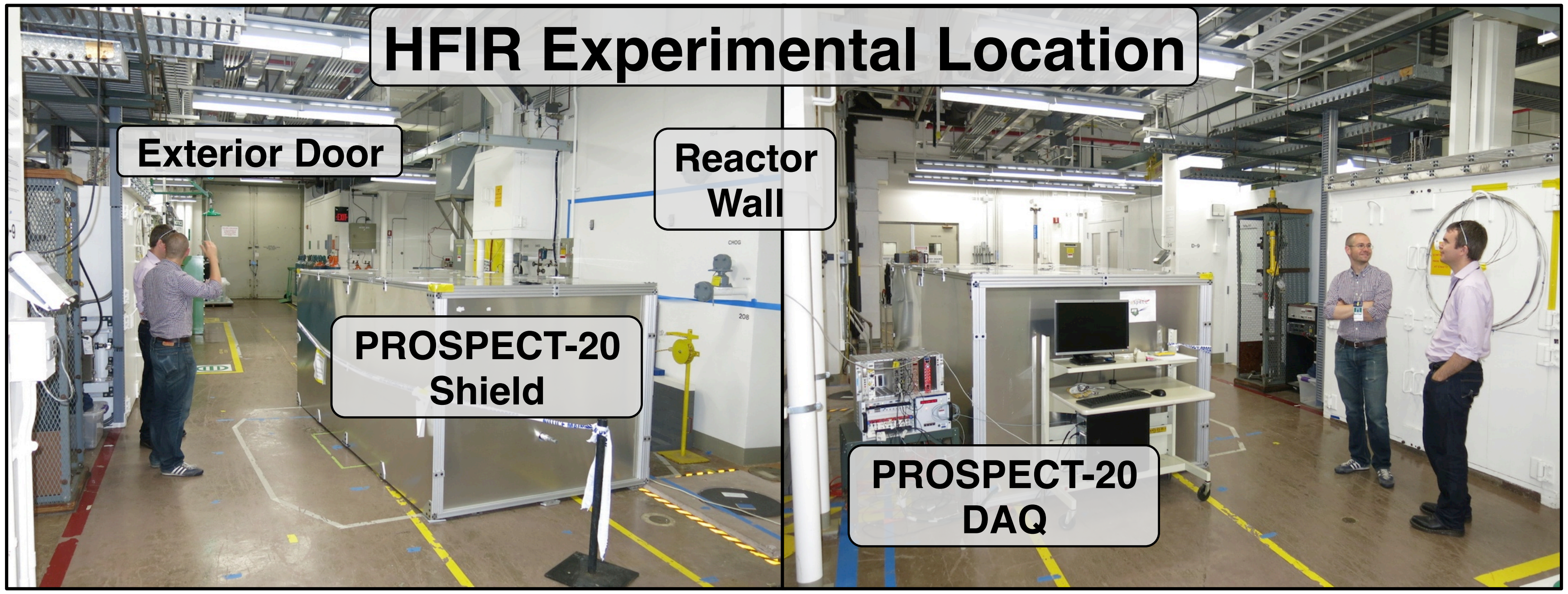


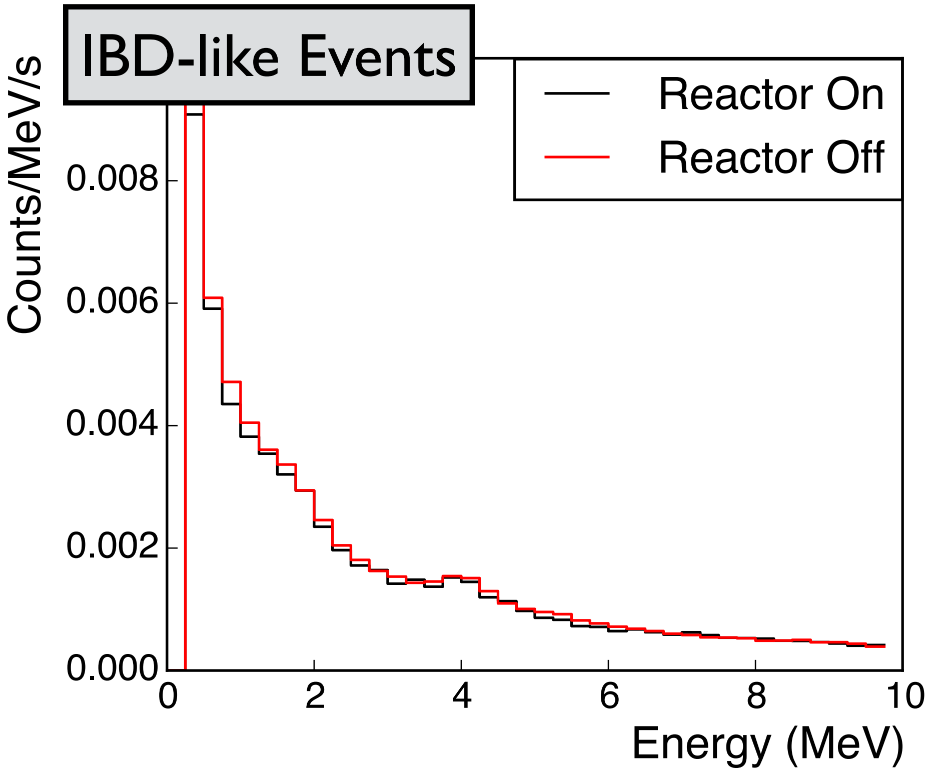




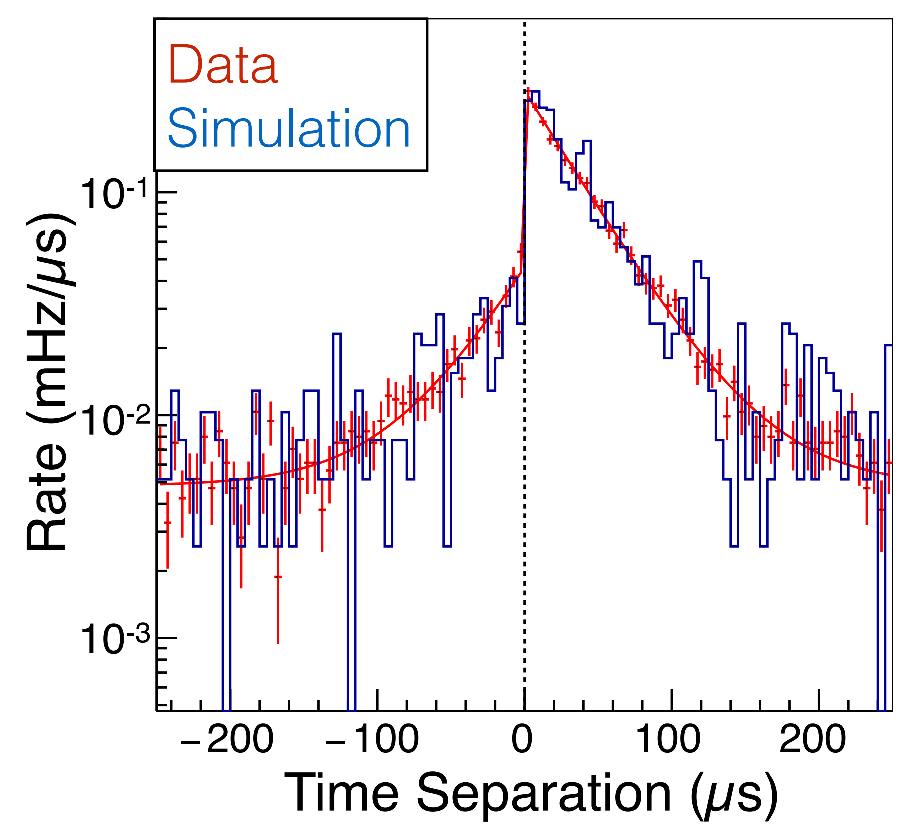
PROSPECT-20 Paper arXiv:1508.06575

PROSPECT-20 at HFIR

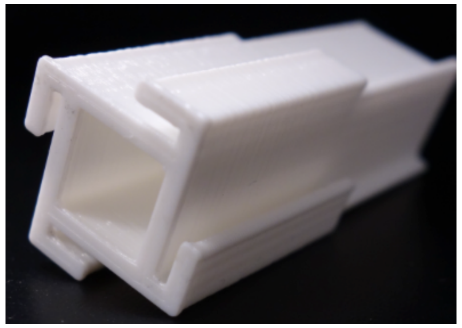


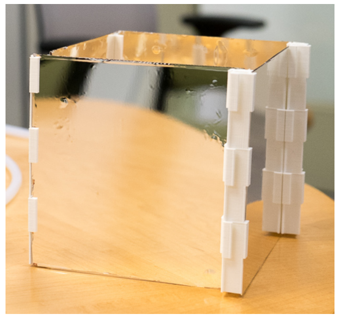


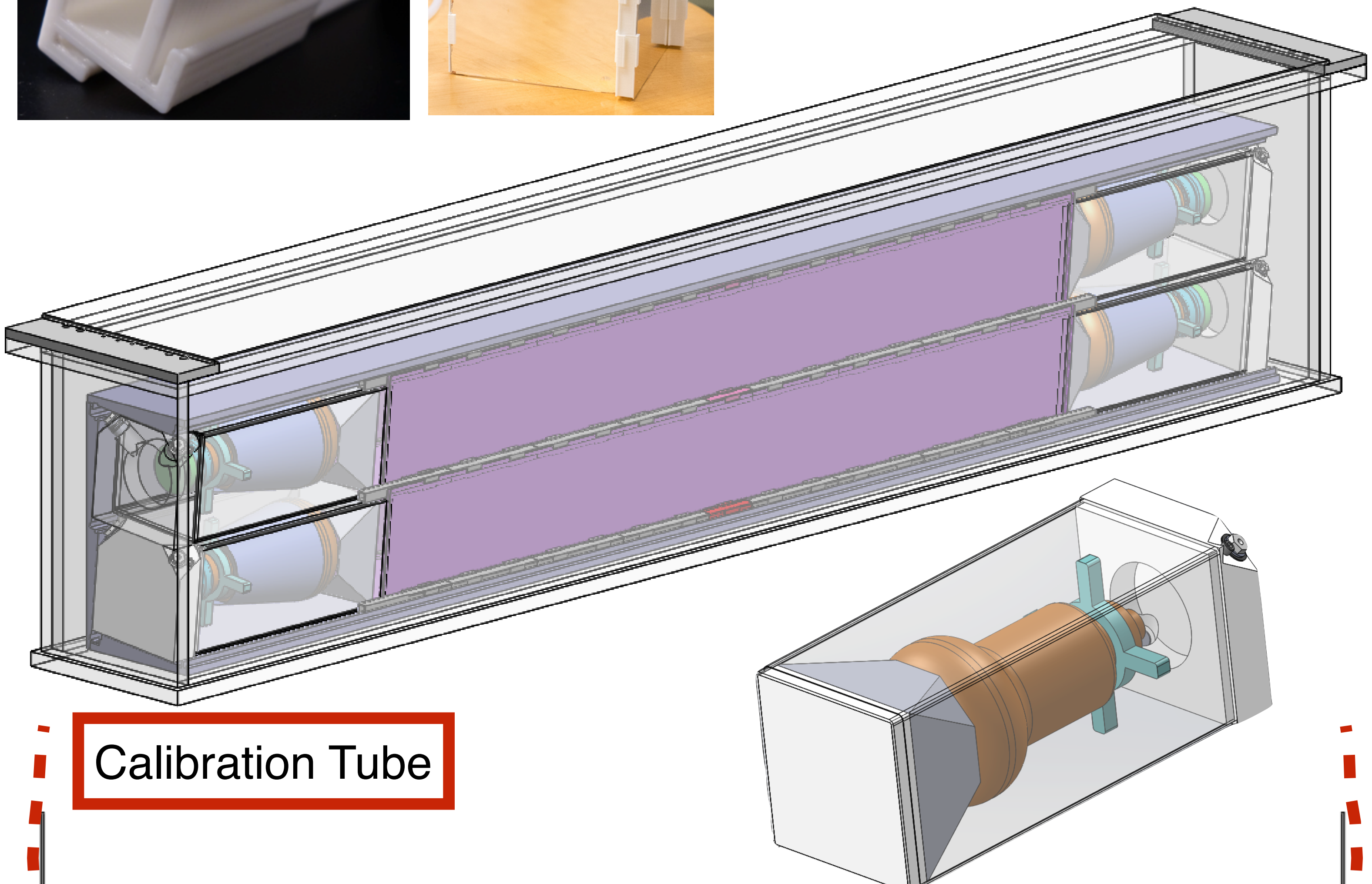
- Operated for four months at HFIR
  - Two HFIR cycles
- Shielding package roughly 25% mass of full shield
- Reactor-related backgrounds mitigated
  - Targeted local shielding
  - Active background rejection with LiLS
- **Validation of background simulations for full PROSPECT detector**

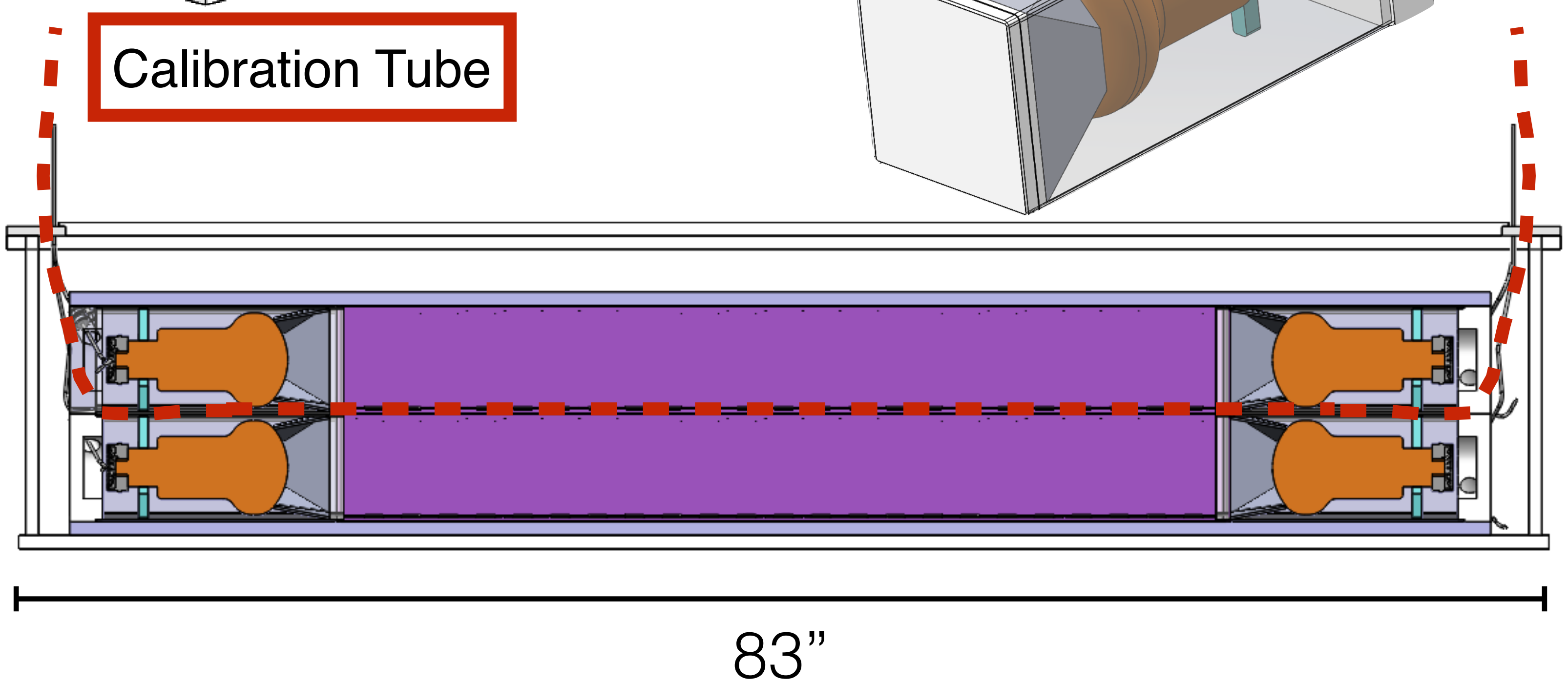


PROSPECT-50 Demonstrator









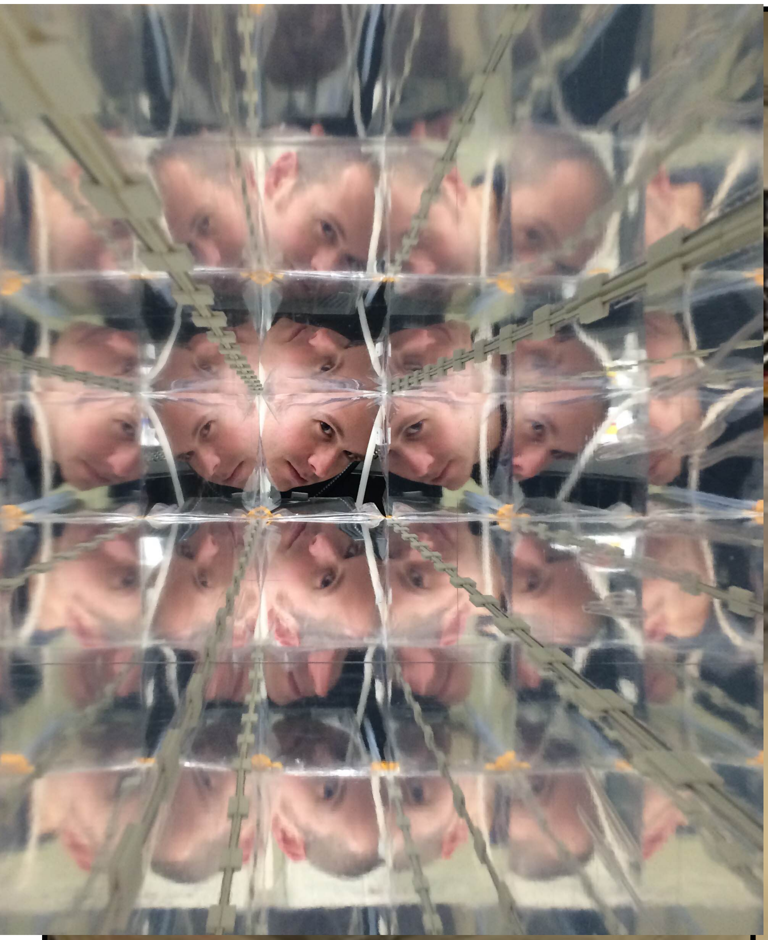
PROSPECT-50:

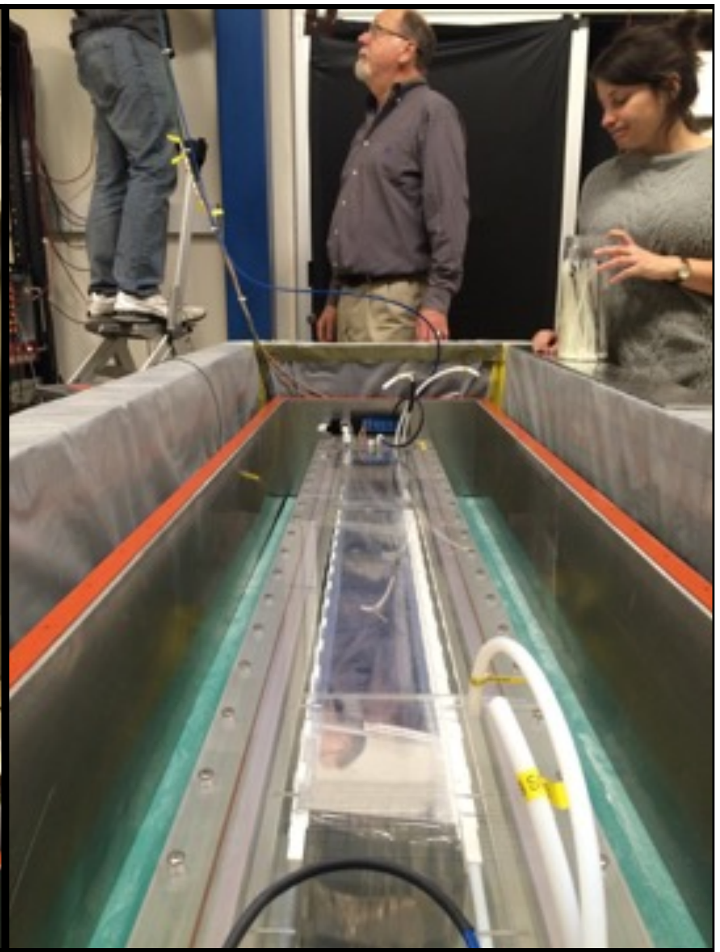
- 50 liters of ^{6}LiLS
- Two PROSPECT segments

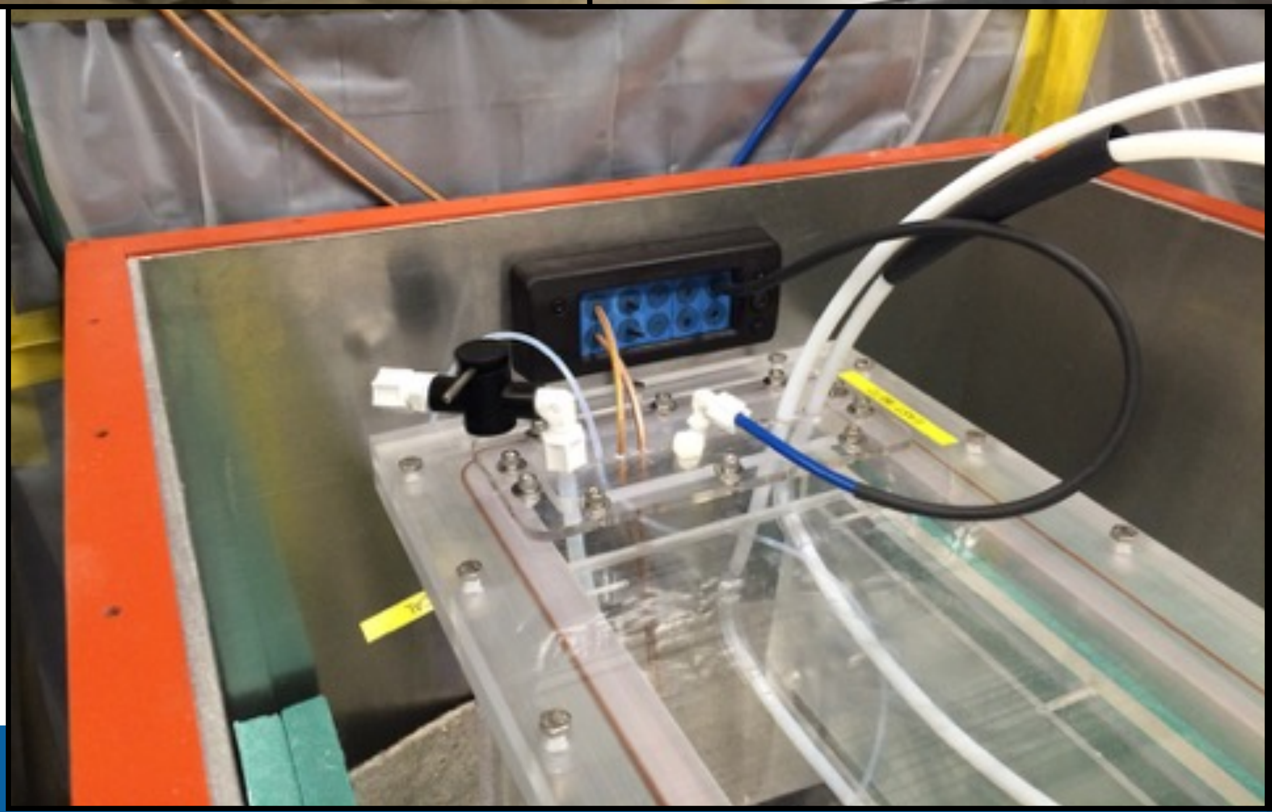
Test platform of each subsystem

- Thin-walled reflector panels
- PMT enclosures
- Filling system and procedure
- Calibration system
  - LED optical
  - Source capsules
- Cell-to-cell variation

PROSPECT-50 Installation

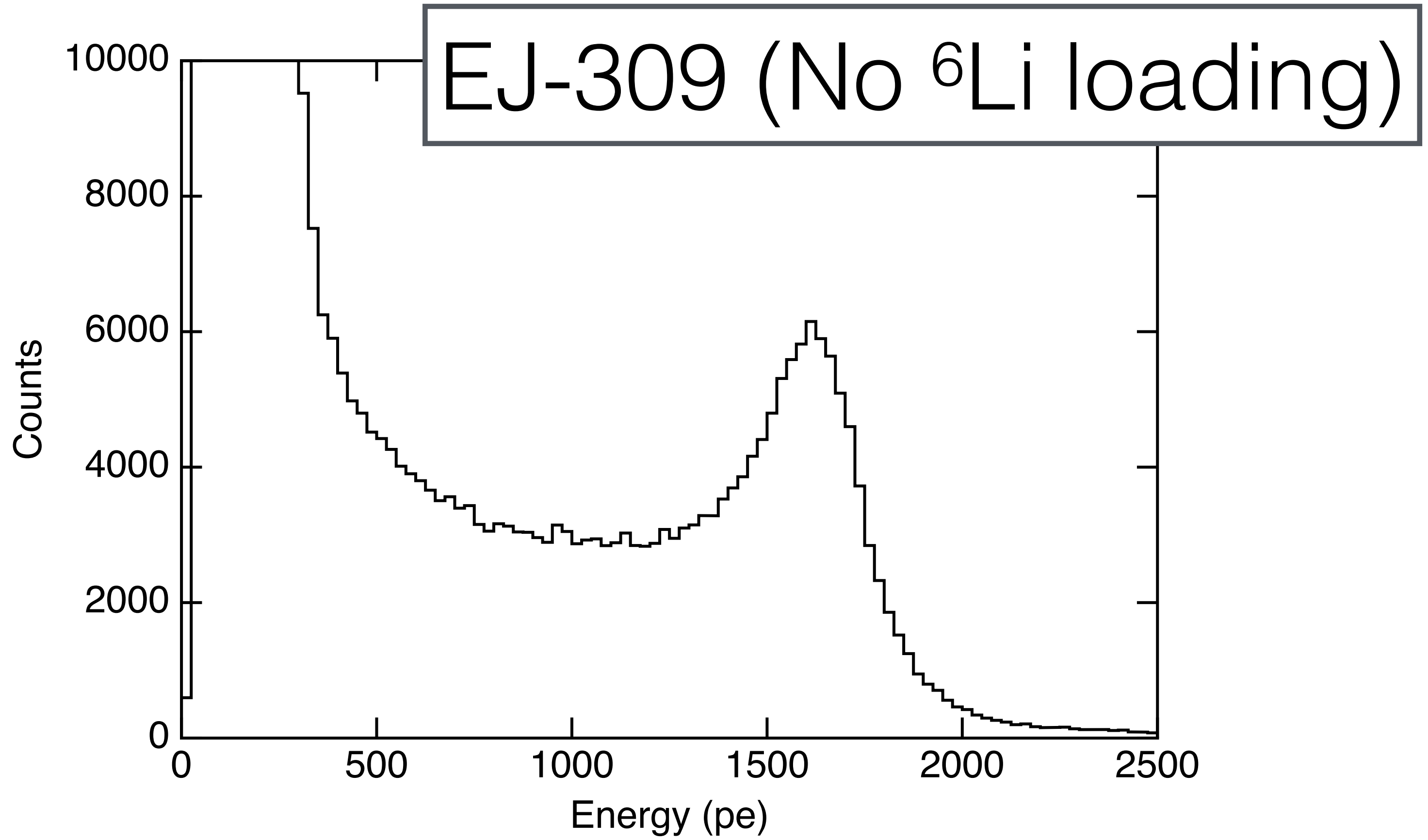


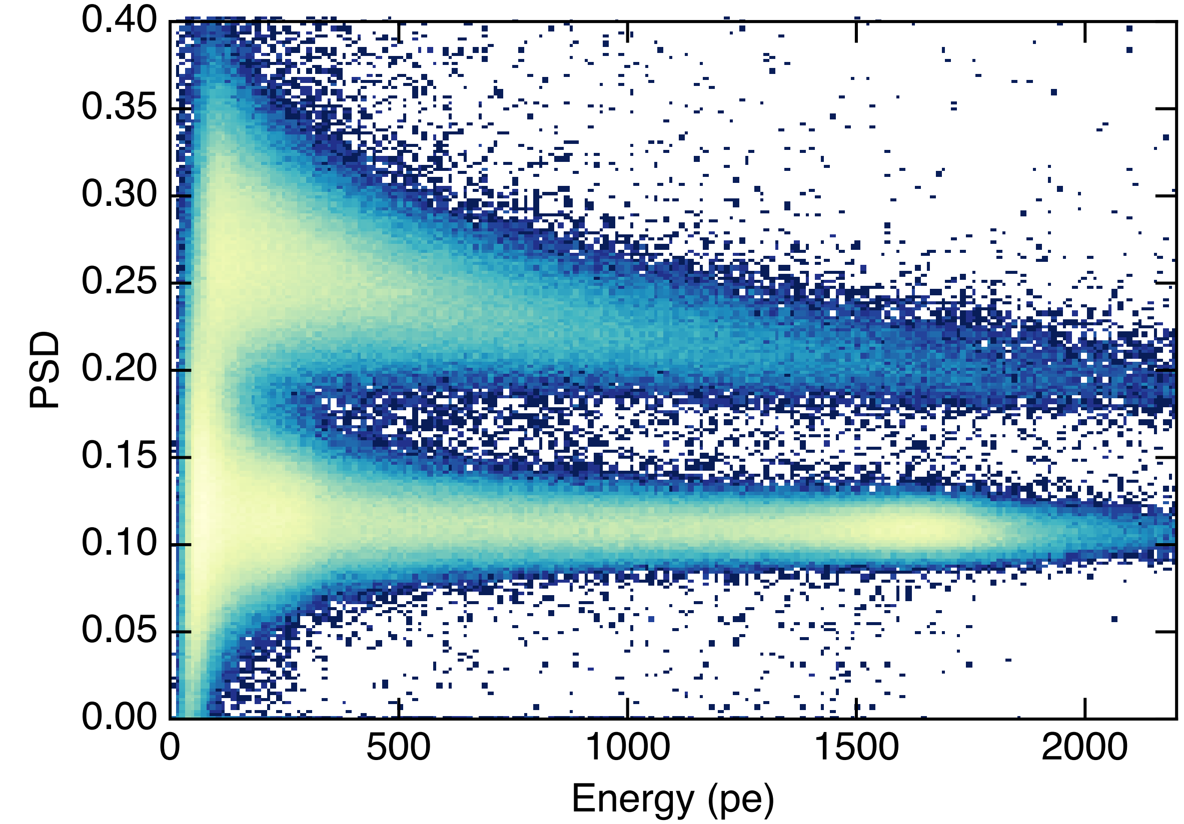




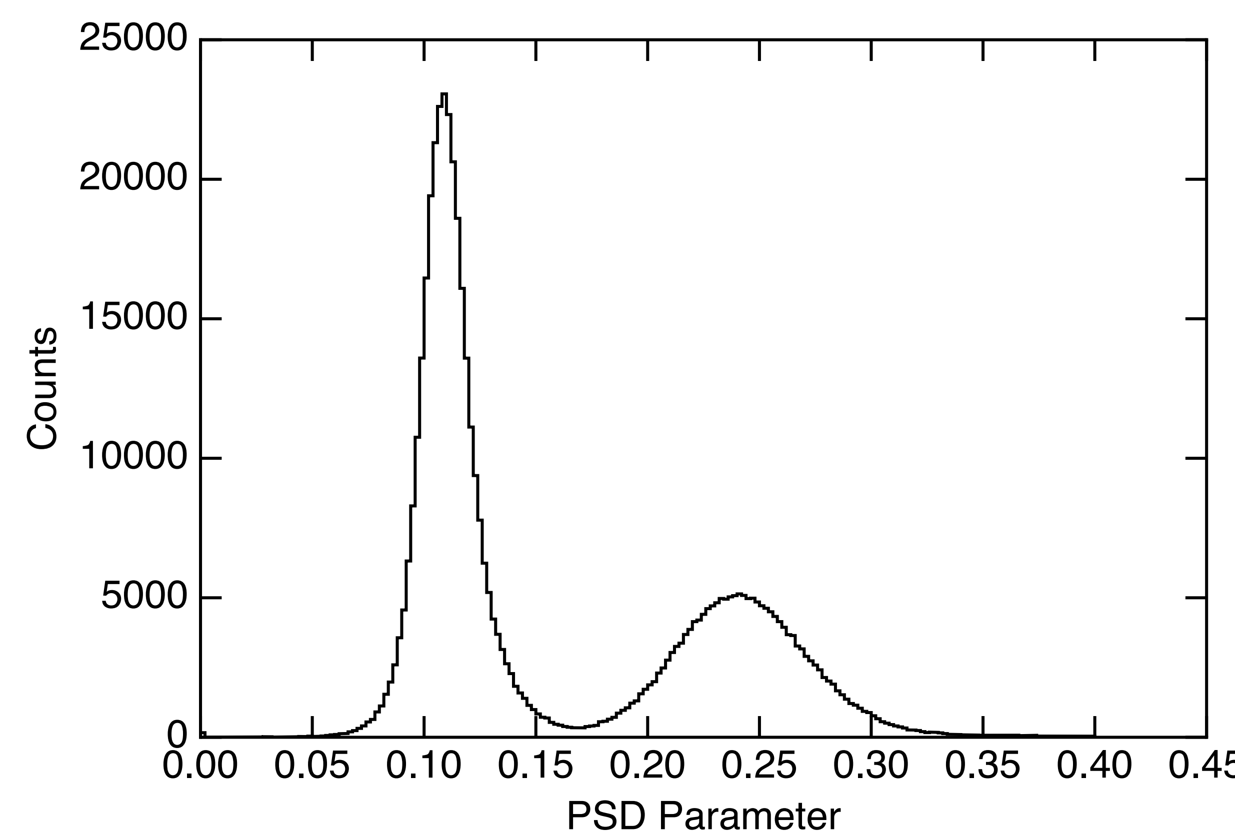
Cf-252 Neutron Data

PROSPECT-50





- Source 30cm above, uniform illumination
- Fitted nH peak: 1615pe (2.0MeV)
- Light Collection 807pe/MeV, same as Bi
- *Excellent PSD performance*



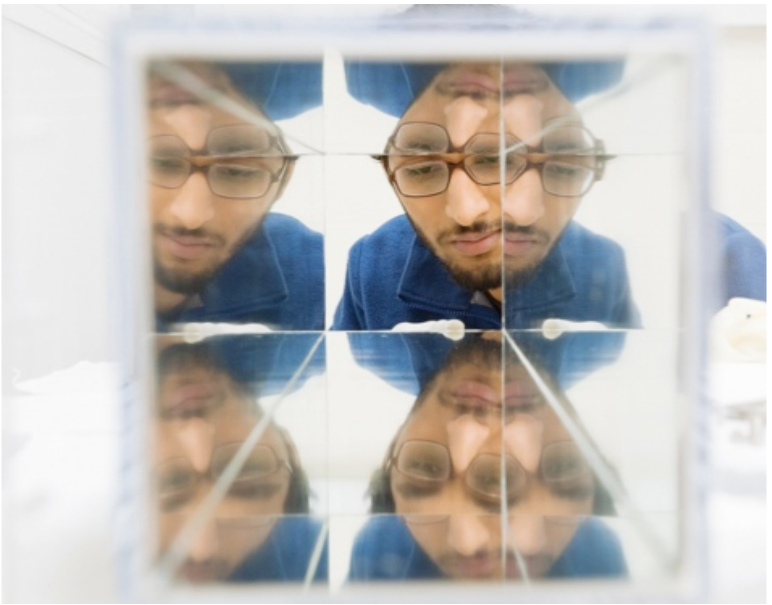
Low-mass optical separators

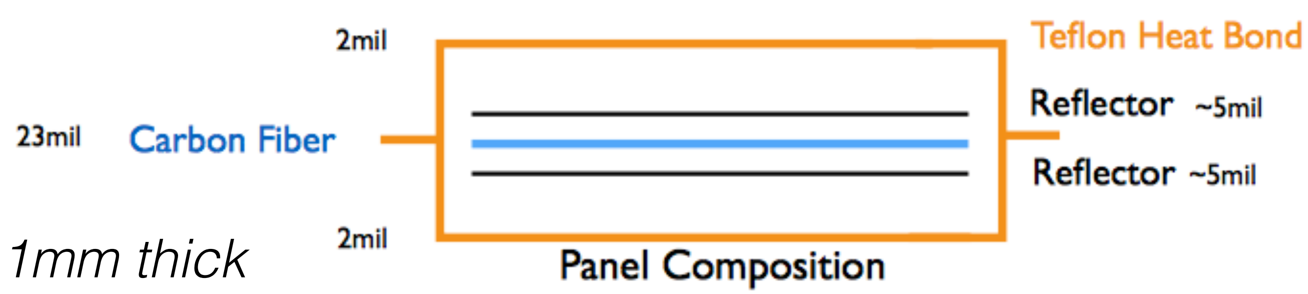
Compatibility:

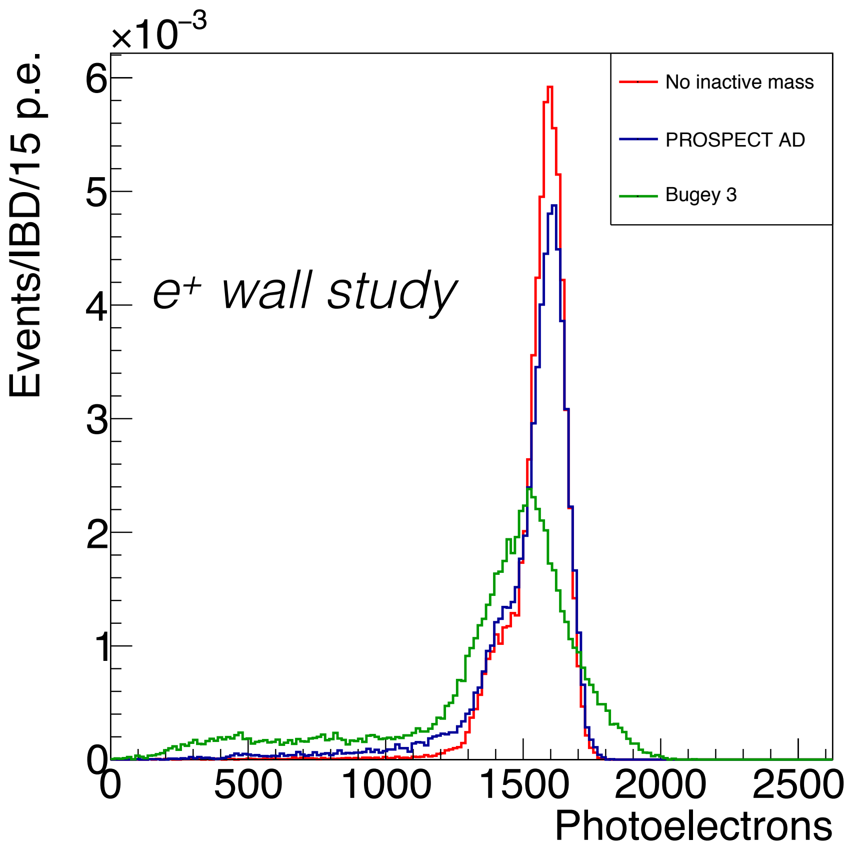
- extensive material compatibility testing required to ensure long-term LS performance
- focus on materials proven in recent experiments - PTFE, acrylic, polypropylene, …
- long-term mechanical stability verified

Separators:

- physics goals demand low inactive mass, high reflectivity, and long-term compatibility
- developed multi-layer system meeting all requirements
- fabrication procedures for full-scale system under validation



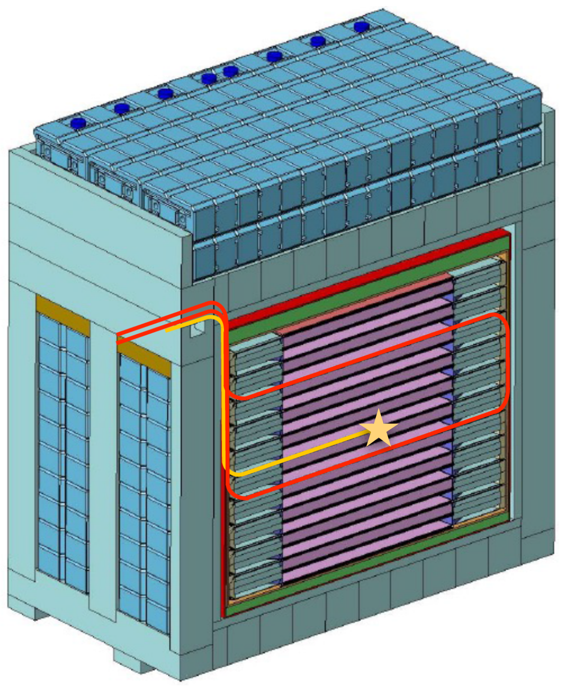




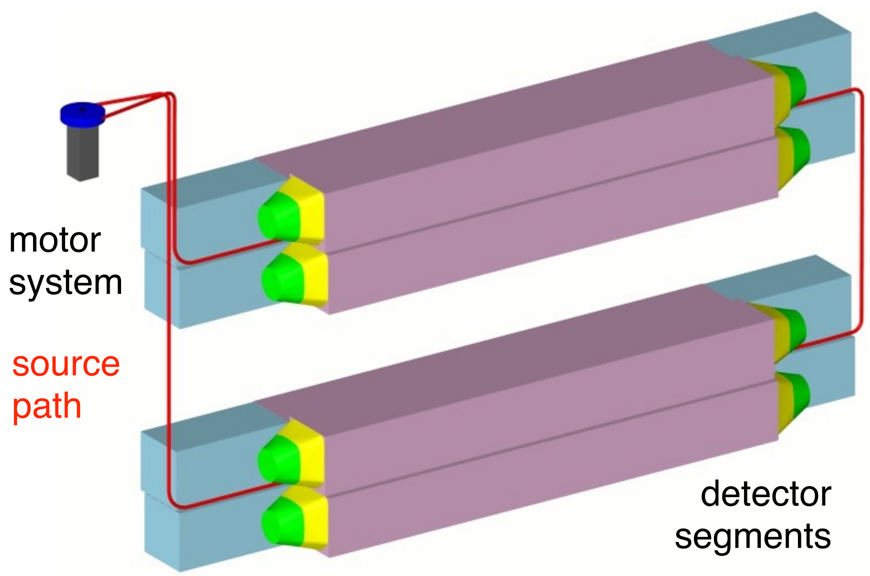
produced robust low-mass separators from LS-compatible materials

Calibration Techniques

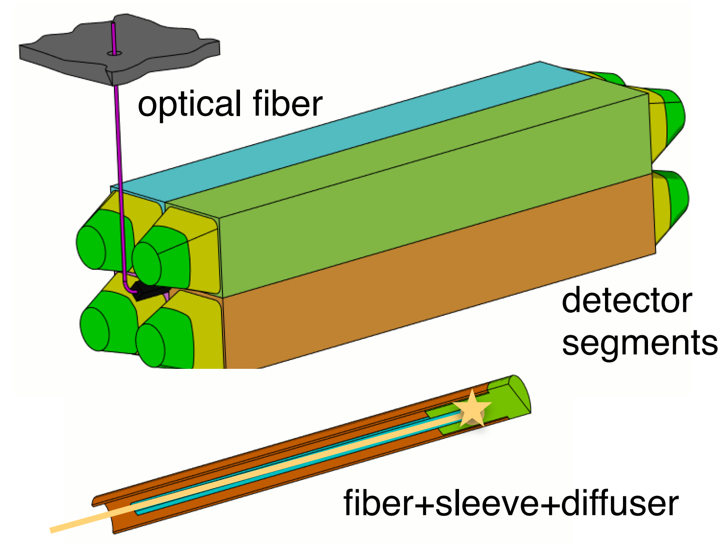
antineutrino detector with optical and **source** calibration



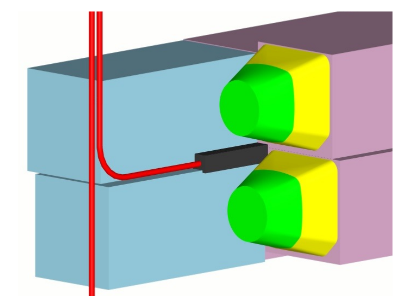
source deployment system with string and guide tubes



optical calibration system with string and guide tubes



routing between segments and PMT modules



pulsed laser sources
- LiLS light transmission
- PMT gain, timing & linearity

encapsulated γ sources
- energy scale
- scintillator non-linearity

neutron sources
- PSD calibration
- neutron detection efficiency

radioactive and cosmogenic backgrounds will be used to monitor and calibrate detector response between source deployments

Example: PROSPECT-20
- through going muons
- ^{40}K
- n capture on ^{6}Li

R&D on scintillator spiking with ^{227}Ac (α,α coinc.)
- segment uniformity, relative LiLS mass measurements

Summary and Outlook

- The reactor flux and shape anomalies need to be resolved: New physics or not?
- PROSPECT will be most sensitive and comprehensive short-baseline reactor experiment worldwide
- **PROSPECT will make a 4σ test of the sterile neutrino best fit after one year**
- **PROSPECT will measure the ^{235}U spectrum with the highest precision to-date**
- Key design goals have been demonstrated and technical implementation is underway

Yale

W&M

University of Waterloo

Concordia cum veritate

High Flux Isotope Reactor

Le Moyne College A·D·1946

Drexel University

Temple University

Illinois Institute of Technology

Oak Ridge National Laboratory

Lawrence Livermore National Laboratory

The University of Tennessee

PROSPECT

Brookhaven National Laboratory

NIST

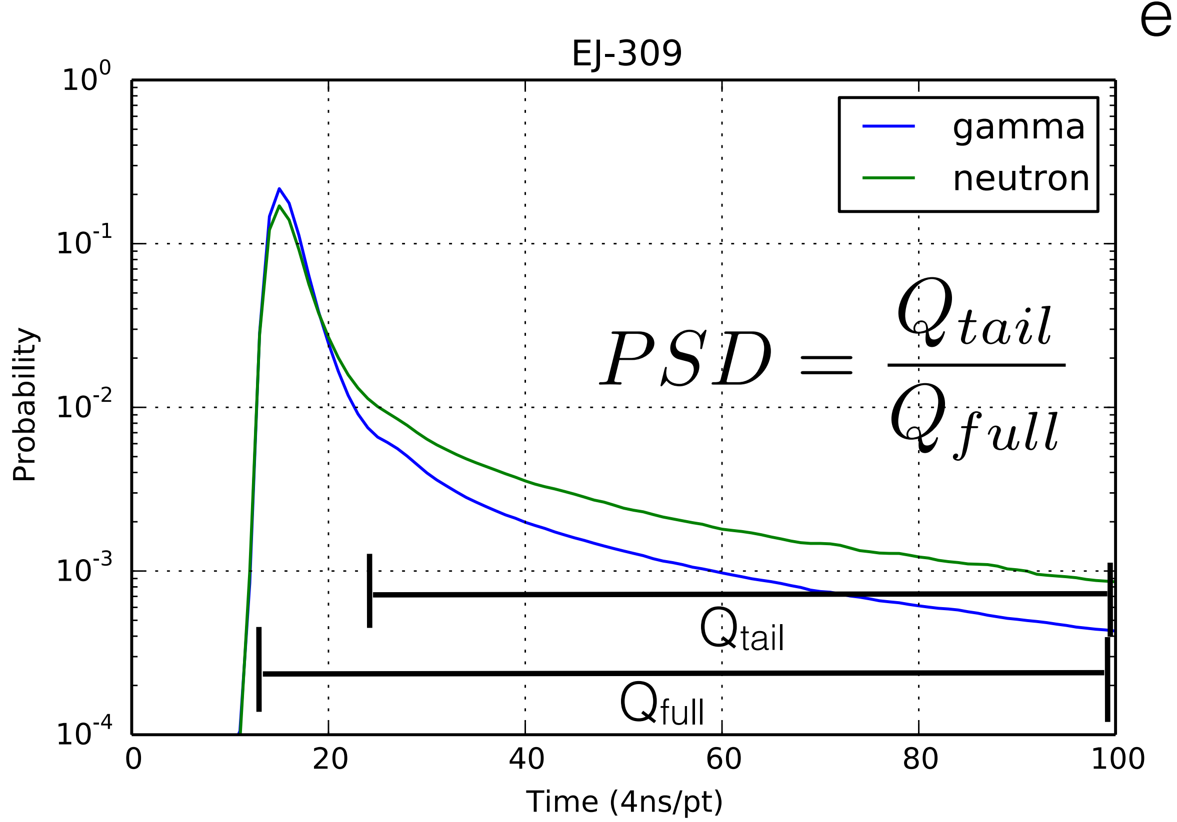
Publications: arXiv: 1309.7647, 1506.03547, 1508.06575, 1512.02202

http://prospect.yale.edu

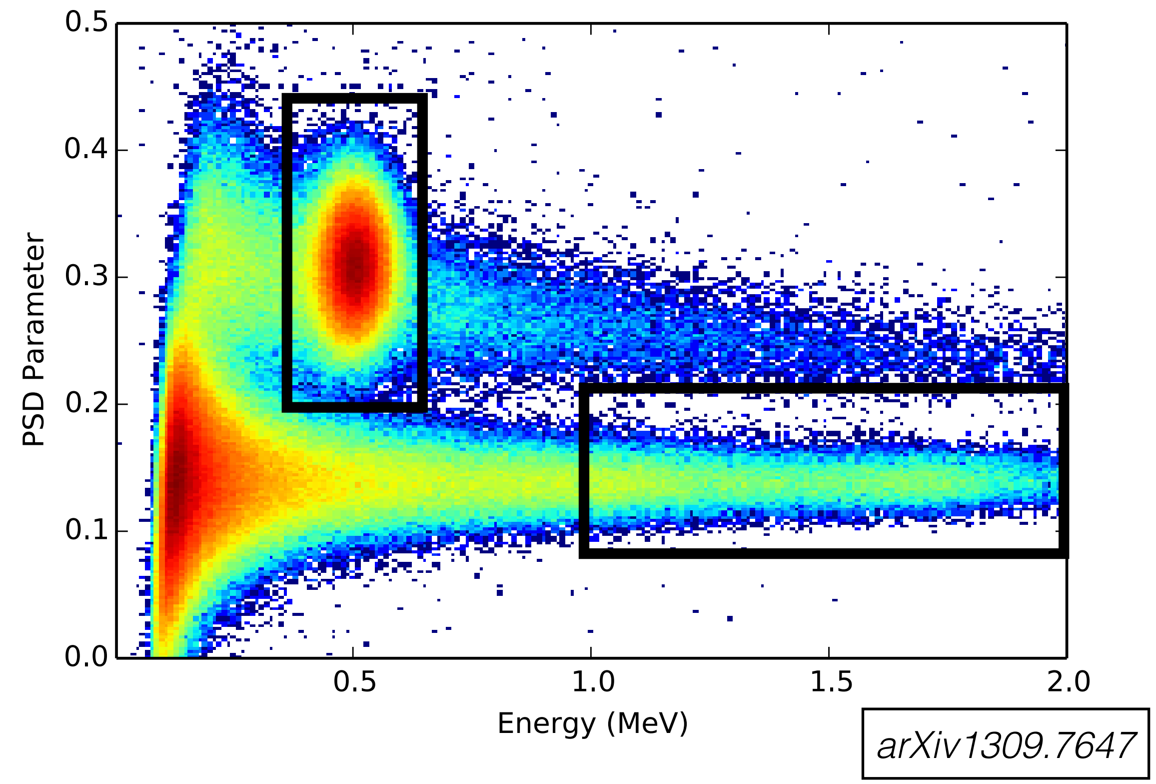
EXTRAS

Pulse Shape Discrimination

Can take advantage of how different particles deposit energy in scintillator using pulse-shape discrimination (PSD). Gives particle identification information.



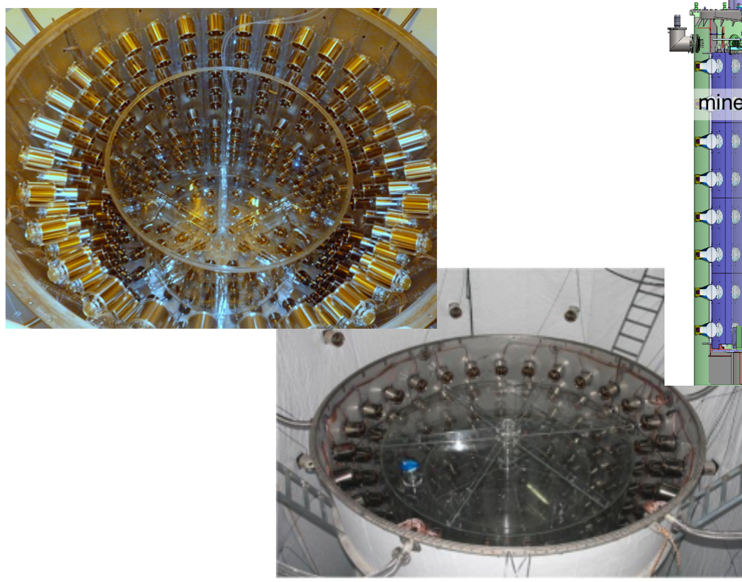
energy+PSD cuts for prompt and delay signals

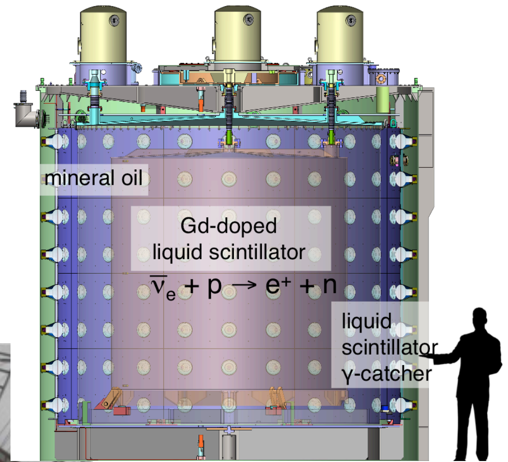


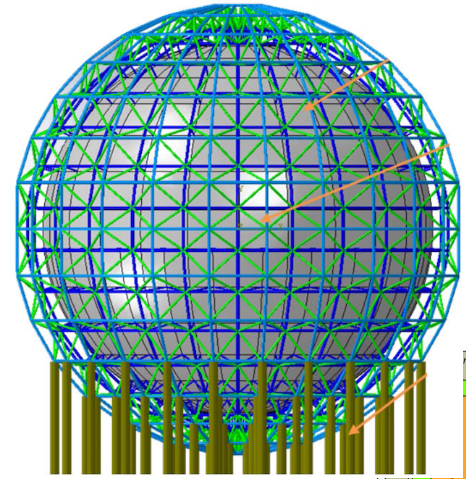
PROSPECT-2 (LiLS)

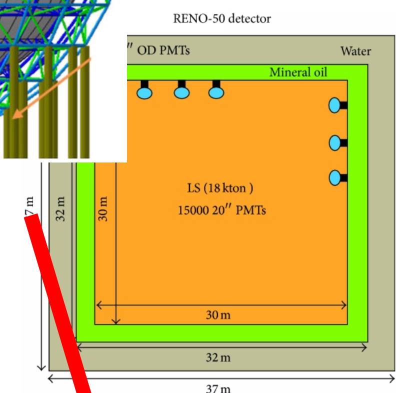
particle classification: light particles = “gamma-like”, heavy charged = “neutron-like”

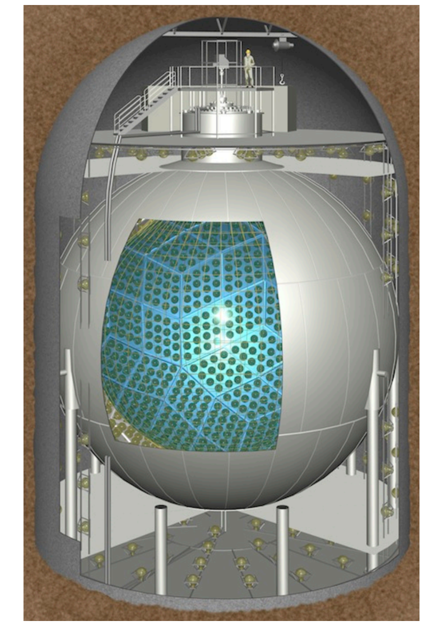
Baselines Probe Different Parameters

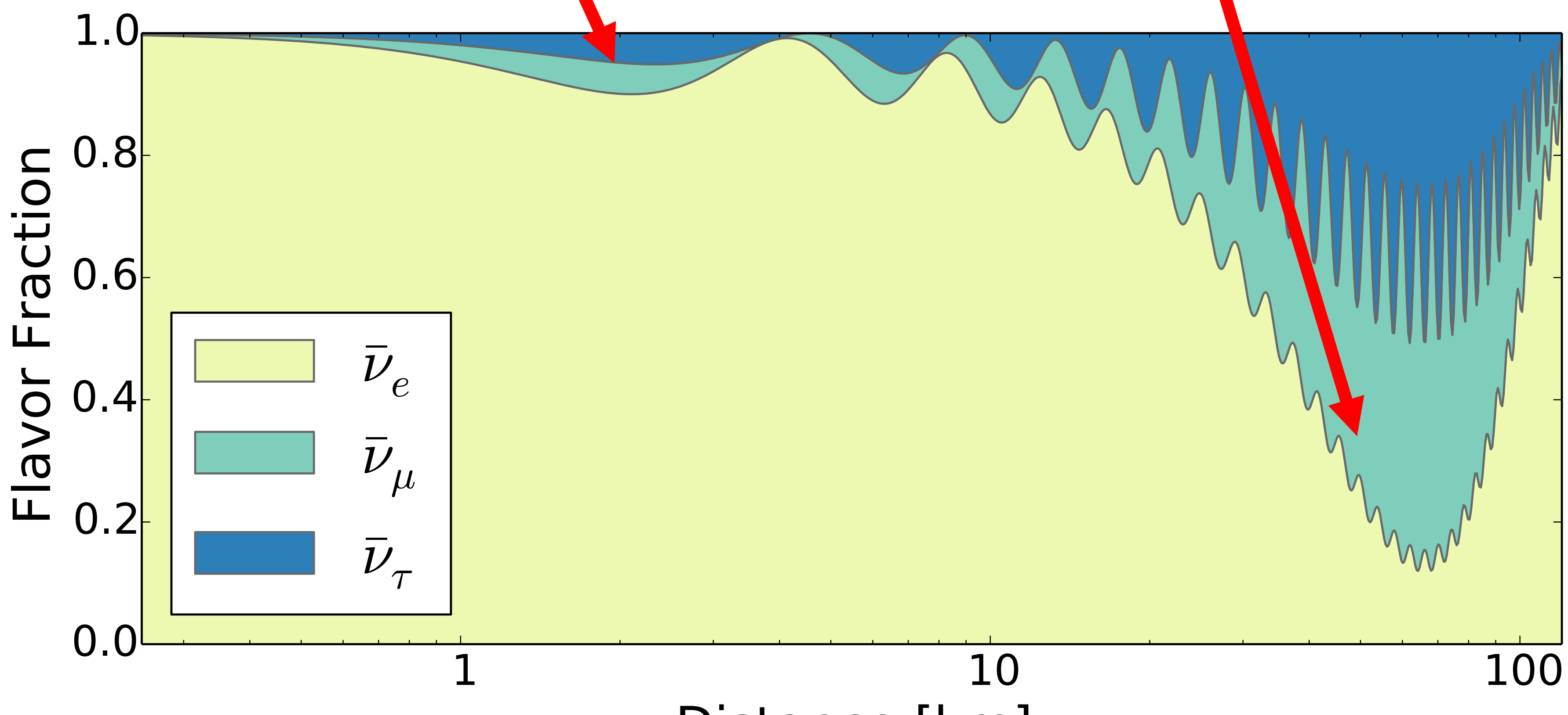






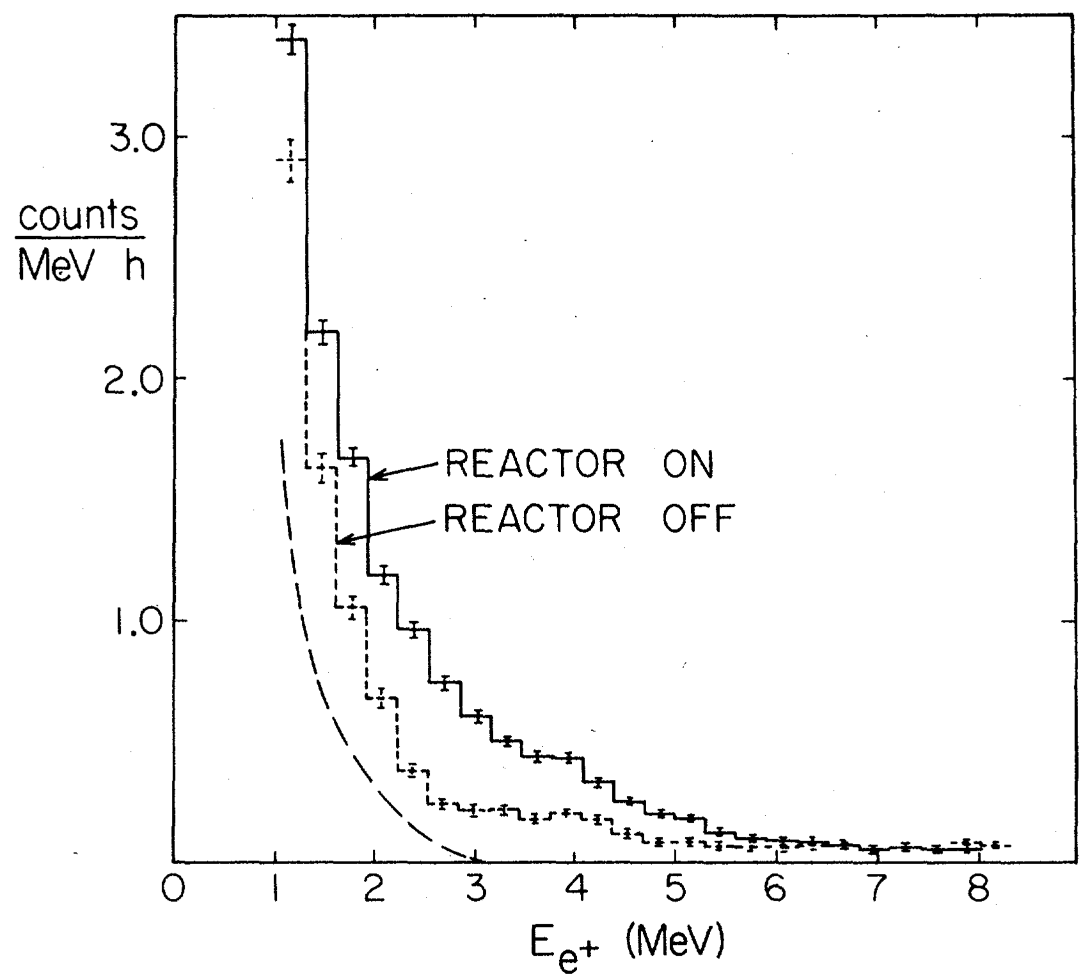


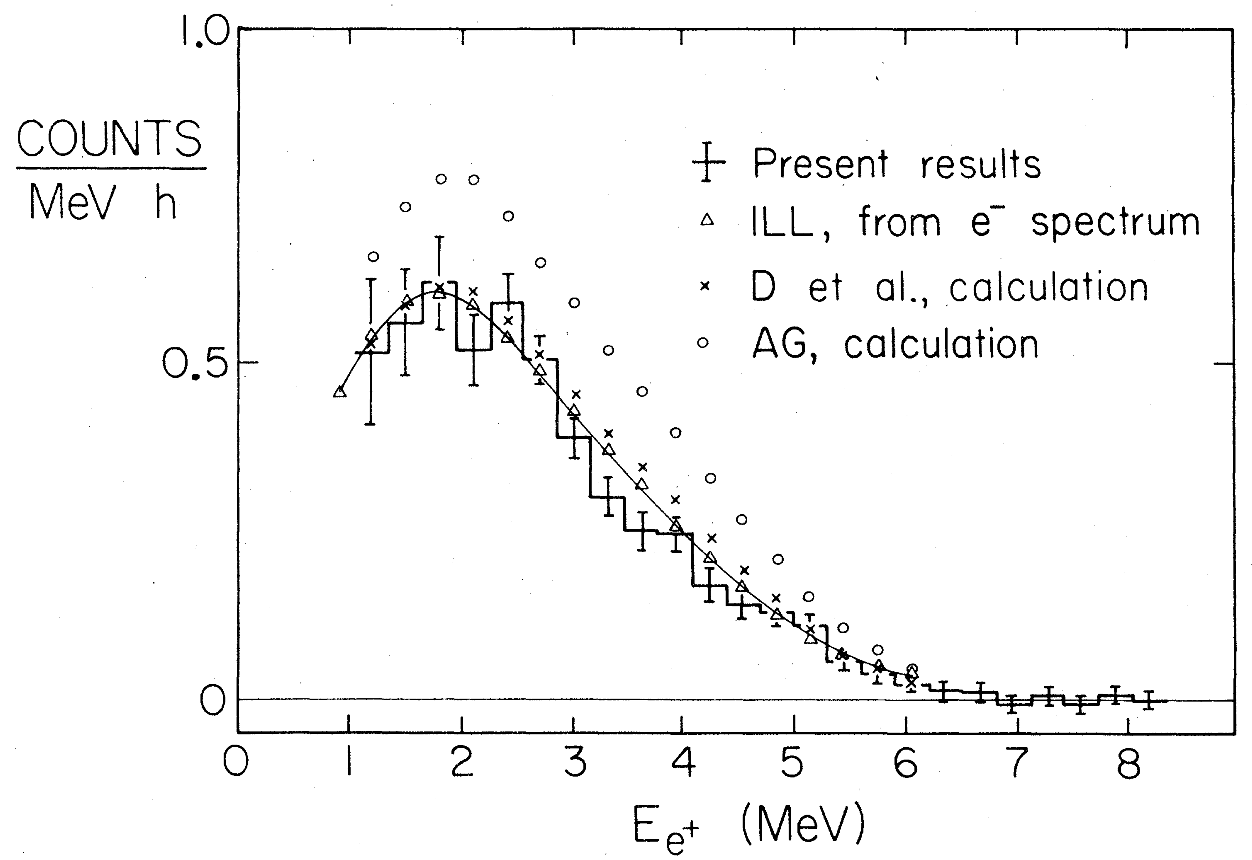




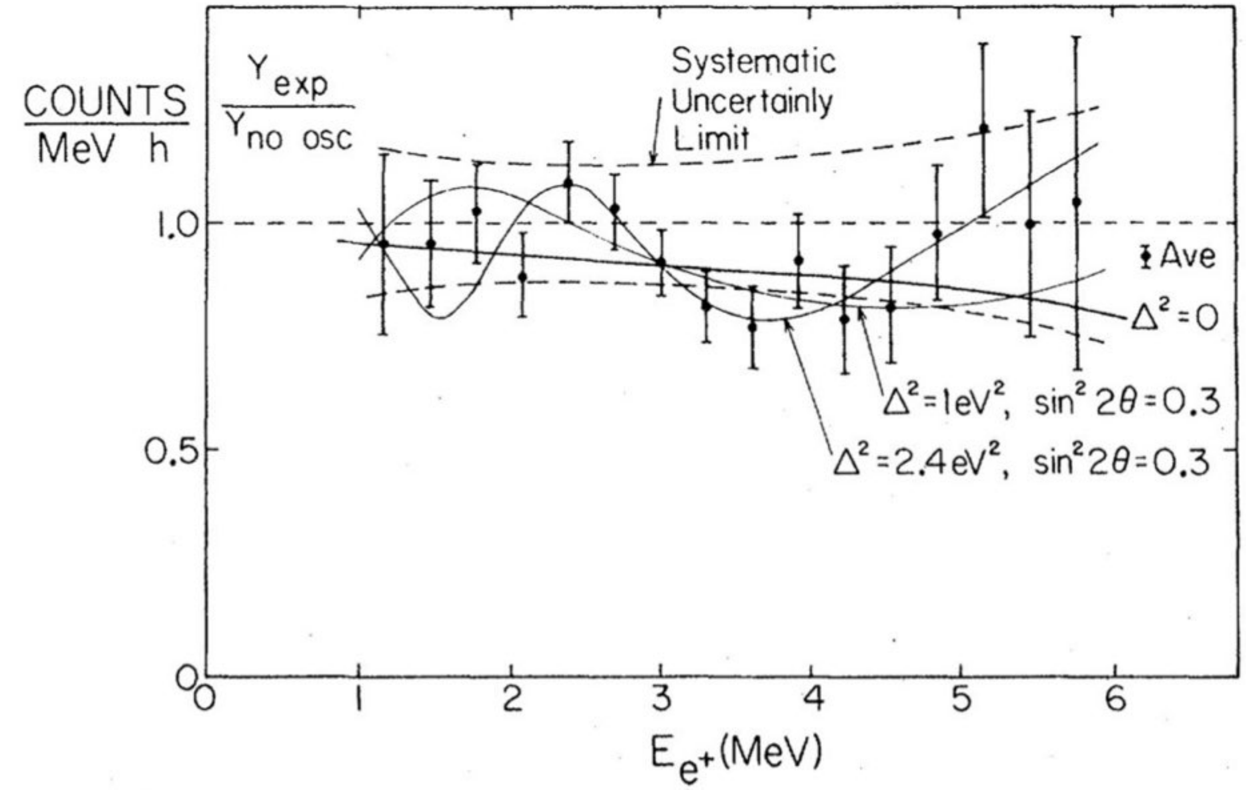
From: Vogel, Wen, Zhang

ILL ^{235}U Spectrum Measurement





- **1981:** Only published measurement of ^{235}U spectrum at ILL reactor in France with S/B ~ 1
- ±20% uncertainties, unable to constrain reactor models
- Fewer than 5000 neutrino events detected



Competition

1. NEOS (Korea): Unsegmented 1000L GdLS at 2.8GW_{th} PWR, 25m baseline, 0.5 yr run started Aug2015

2. Neutrino-4 (Russia): Movable, segmented 14m^3 GdLS, 6-12m baseline at 100MW SM-3 reactor

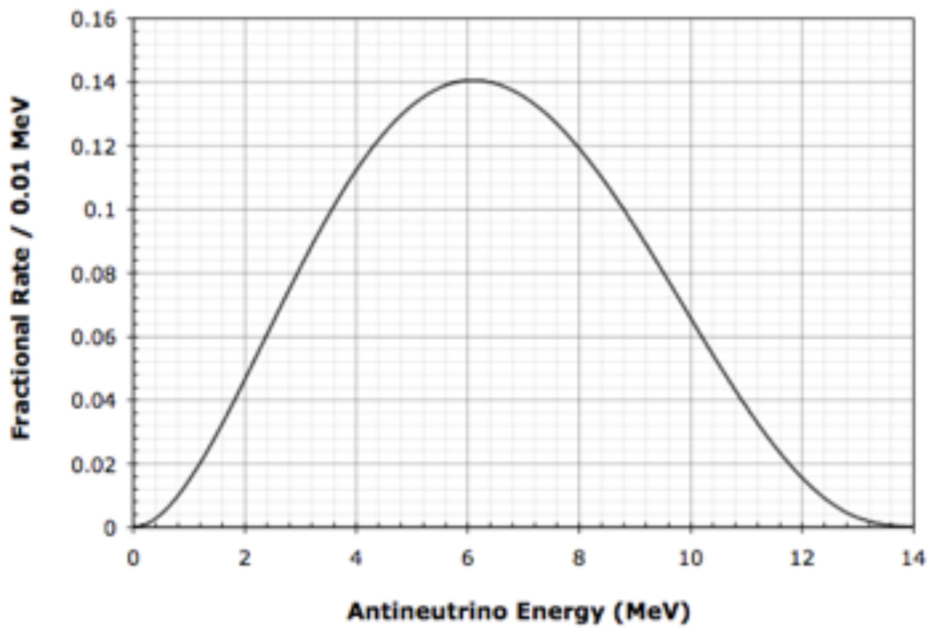
3. SOLID(EU): Segmented 2t PS/6LiFZnS, 5-10m baseline at 72MW BR2 reactor, starting 2nd half 2016

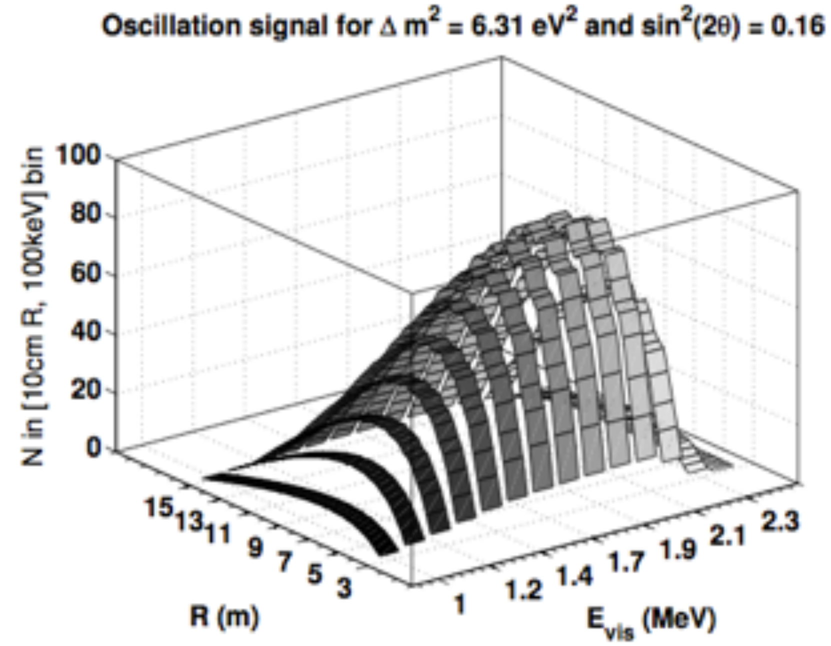
4. STEREO(EU): Segmented, 1.7t GdLS, 9-11m baseline, at ILL 57MW reactor, has observed neutrinos but has high levels of reactor-related background, first data fall 2016

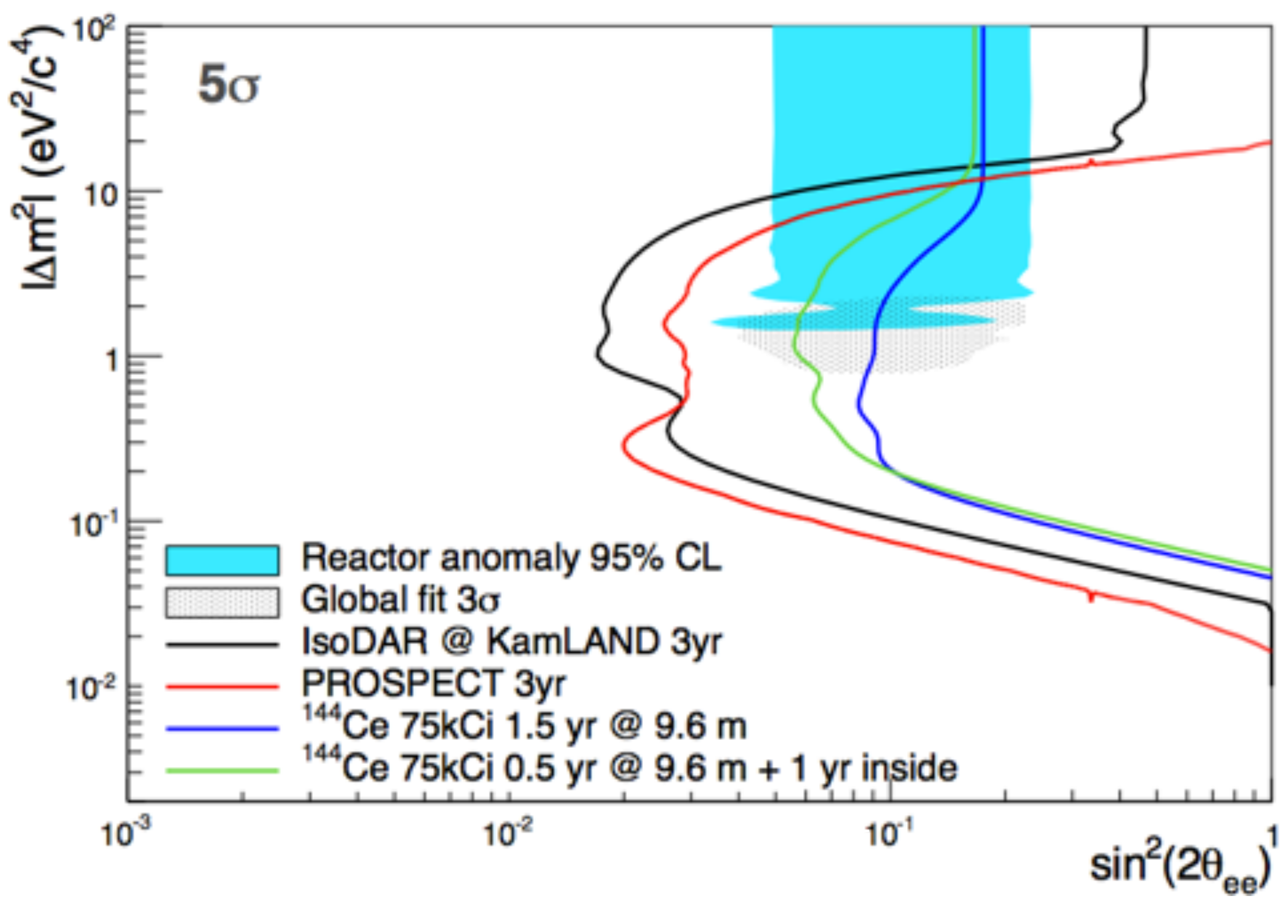
5. CeSOX: ~4PBq ^{144}Ce-^{144}Pr antineutrino source at Borexino, planning for fall 2016 deployment

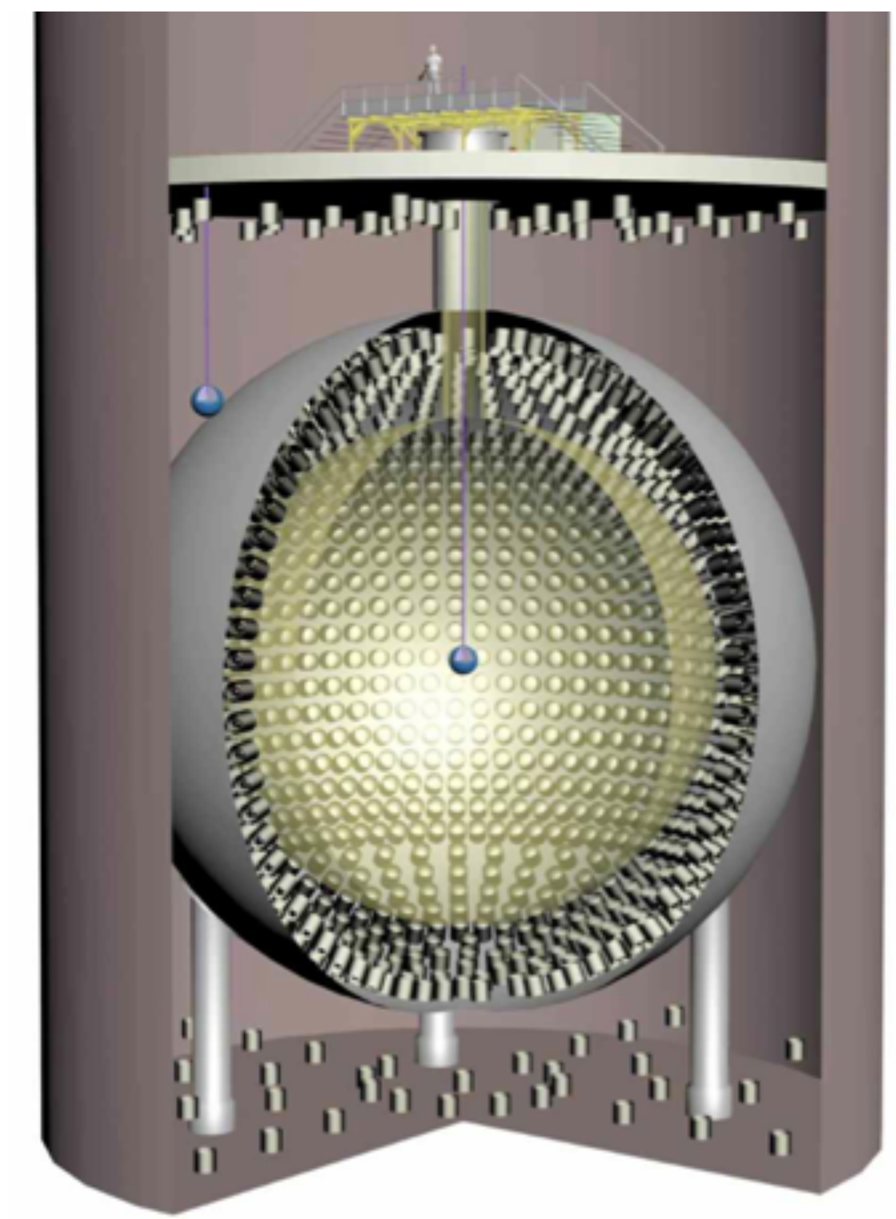
Competing Efforts

- CeLAND and SOX: Radioactive source experiments: quick-ish
- IsoDAR: Accelerator-produced beta decay source: longer timescale









arXiv:1312.0896

arXiv:1307.2949

arXiv:1304.7721

SBL Reactor Context

- PROSPECT: designed to provide a precision measurement for BOTH key physics goals
  - Moveable segmented detectors give best mapping of oscillation space
  - Design enables higher energy resolution other efforts
- PROSPECT has the experience, development, and infrastructure in place for the world's pre-eminent SBL reactor effort.

A (biased) overview of global efforts — Good : Not Good

	Effort	Dopant	Good X-Res	Good E-Res	L Range (meters)	Fuel	Exposure, MW*ton	Move-able?	Running at intended reactor?
US	**PROSPECT**	**Li**	**Yes**	**Yes**	**6.5-20**	**HEU**	**185**	**Yes**	**Yes**
	NuLat	Li/B	Yes	Yes	TBD	TBD	TBD	Yes	No
EU	Nucifer	Gd	No	Yes	7	HEU	56	No	Yes
	STEREO	Gd	Yes	Yes	9-11	HEU	100	No	Yes
	SoLid	Li	Yes	No	6-8	HEU	155	No	Yes
Russia	DANSS	Gd	Yes	No	9.7-12	LEU	2700	Yes	Yes
	Neutrino4	Gd	Yes	No	6-12	HEU	150	Yes	Yes
Asia	NEO	Li/Gd	No	Yes	20-ish	LEU	30	No	No