KamLAND

- Introduction to KamLAND
- Detector Construction
- Physics Data from KamLAND
- Summary

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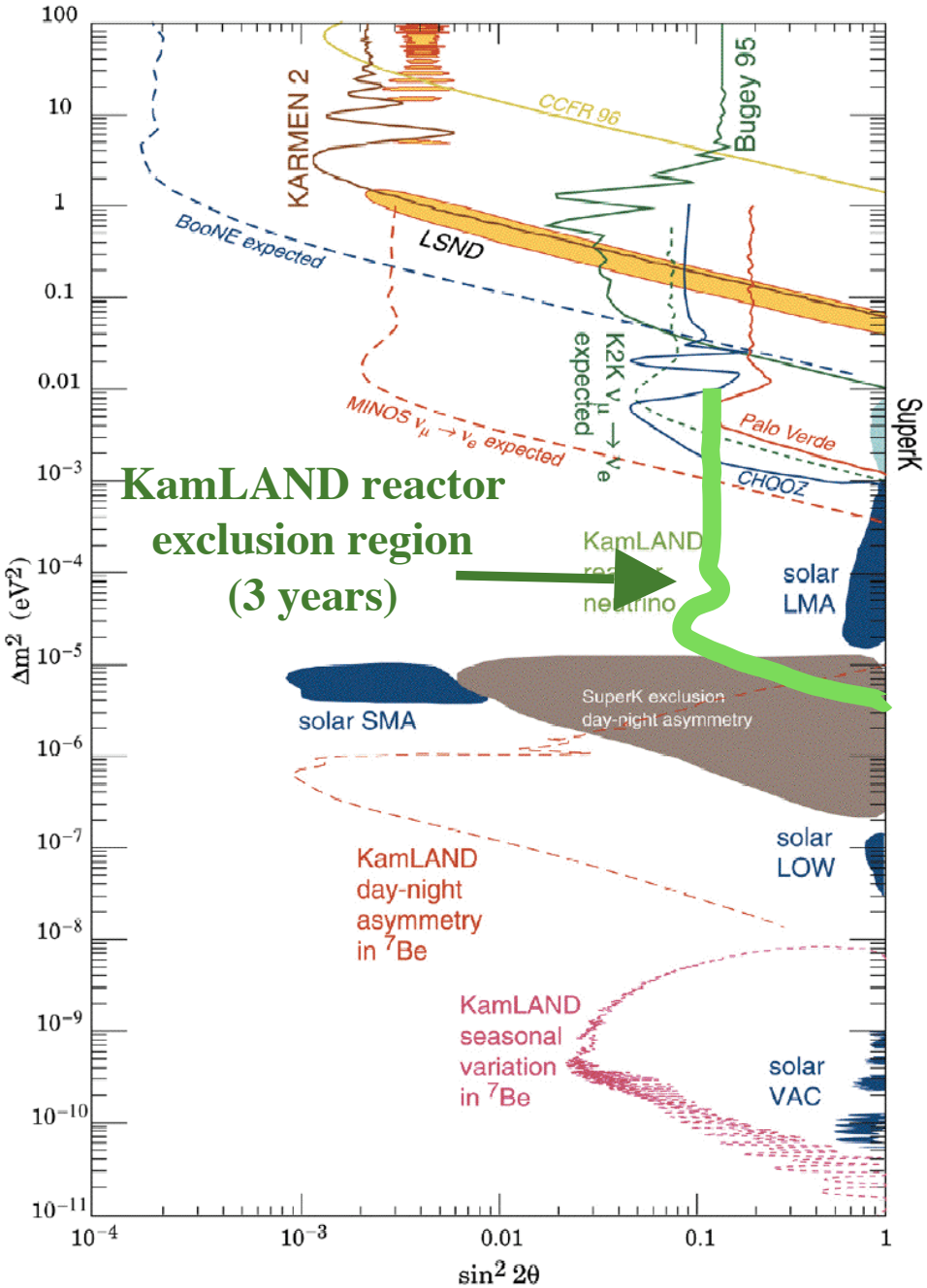
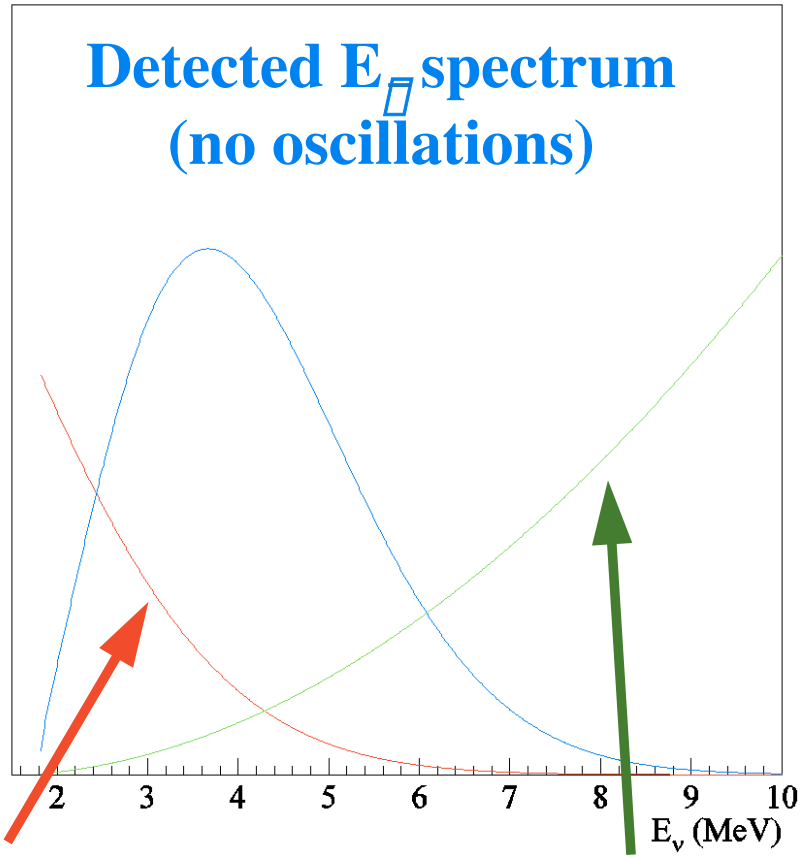
Introduction to KamLAND



- Kamioka Liquid_Scintillator Antineutrino Detector
- KamLAND is a neutrino oscillation experiment that uses a terrestrial source of neutrinos to look at the solar neutrino problem
- KamLAND is a long_baseline experiment to study the disappearance of electron antineutrinos ($\bar{\nu}_e$)
- Liquid Scintillator allows us to probe lower neutrino energies than water _herenkov detectors

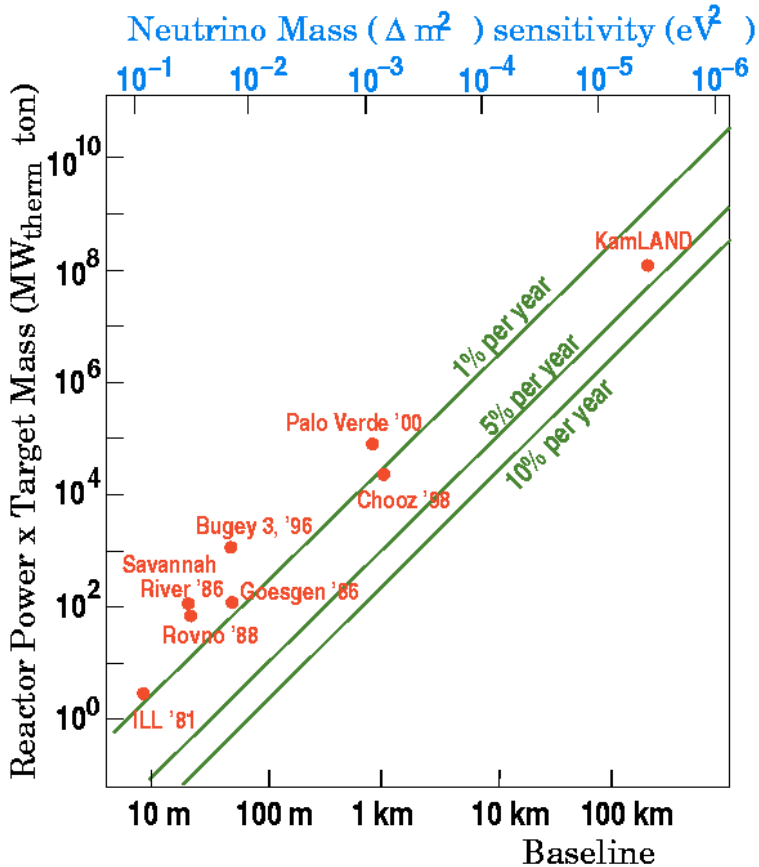
Introduction to KamLAND

KamLAND is part of a tradition of experiments that detect neutrinos from nuclear power plants



Reactor $\bar{\nu}_e$ spectrum

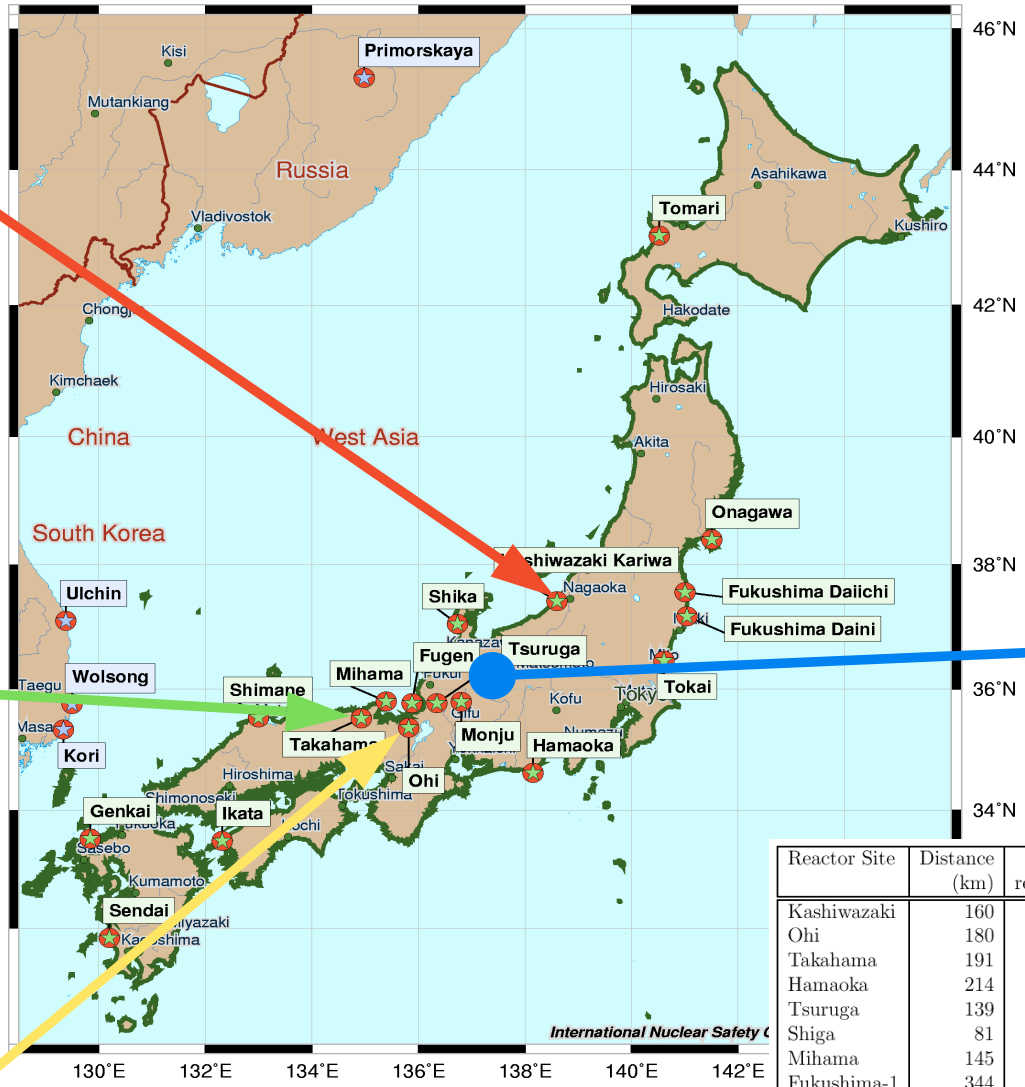
Cross section for $\bar{\nu}_e + p \rightarrow e^+ + n$



Coincidence signal: detect

- Prompt: e^+ annihilation
- Delayed: **n** capture
  200 μs capture time

Introduction to KamLAND



KamLAND uses the entire Japanese nuclear power industry as a long_baseline source

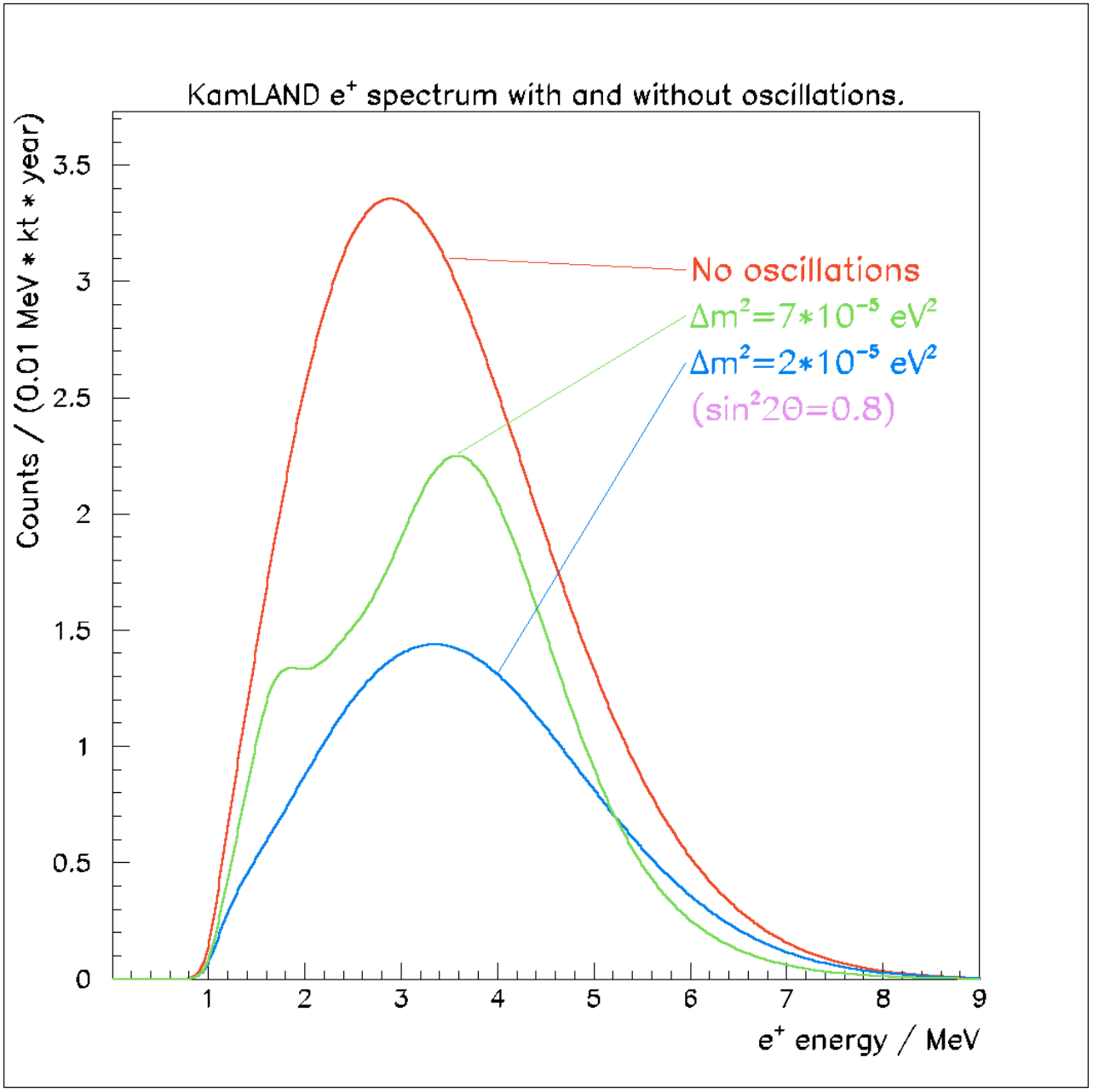
KamLAND

80% of flux from baselines 140_210 km

Reactor Site	Distance (km)	# of reactors	Therm. Power (max) (GW)	Max. Flux (10^5 $\bar{\nu}_e$ /cm^2/s)	Max.Event rate events/kt-year
Kashiwazaki	160	7	24.6	4.25	348
Ohi	180	4	13.7	1.90	154
Takahama	191	4	10.2	1.24	102
Hamaoka	214	4	10.6	1.03	84
Tsuruga	139	2	4.5	1.03	84
Shiga	81	1	1.6	1.08	89
Mihama	145	3	4.9	1.03	84
Fukushima-1	344	6	14.2	0.53	44
Fukushima-2	344	4	13.2	0.49	40
Tokai-II	295	1	3.3	0.17	14
Shimane	414	2	3.8	0.10	8
Ikata	561	3	6.0	0.08	7
Genkai	755	4	6.7	0.05	4
Onagawa	430	2	4.1	0.10	8
Tomari	784	2	3.3	0.02	2
Sendai	824	2	5.3	0.03	3
Total		51	130	13.1	1075

Introduction to KamLAND

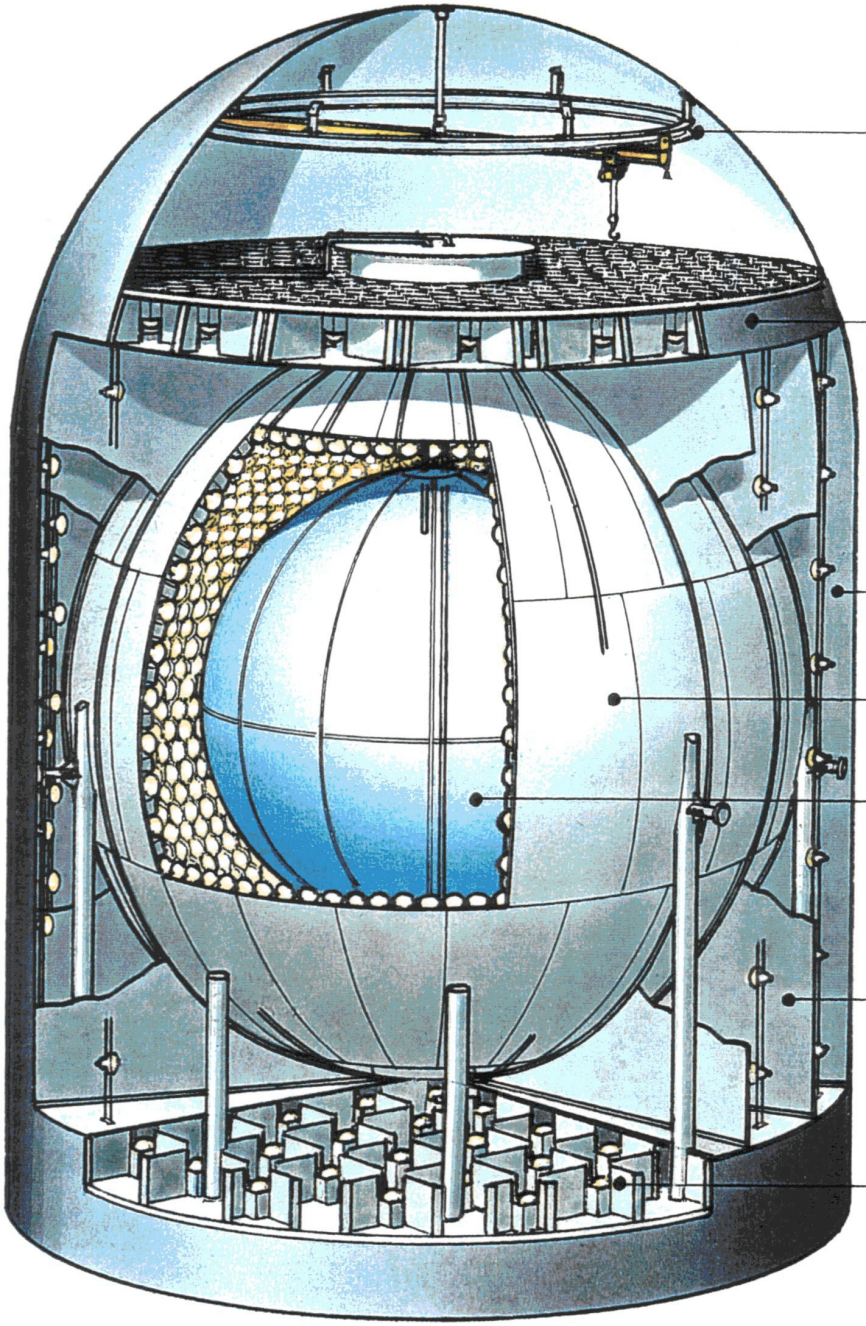
Neutrino oscillations change both the rate and energy spectrum of the detected events



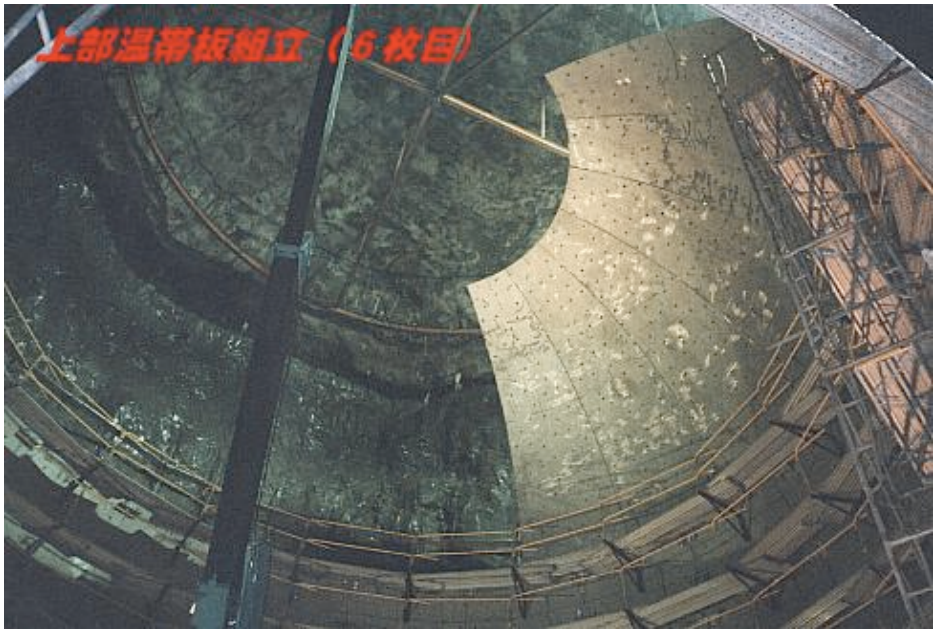
Note: this is the energy released by the positron annihilation, not the neutrino energy

Introduction to KamLAND

- 1 kton liquid scintillator
  - 80% dodecane
  - 20% pseudocumene
  - 1.5 g/L PPO
- Paraffin outside the
  120-□m nylon balloon
  - radon barrier
- 1879 PMT's
  1325 17" _ fast
  554 20" _ efficient
- 225 Veto PMT's
  Water _herenkov

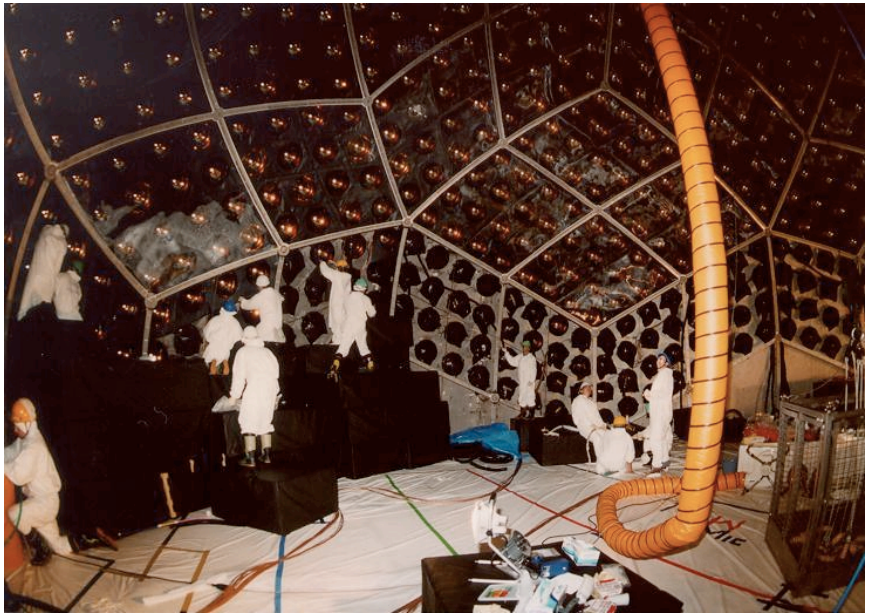


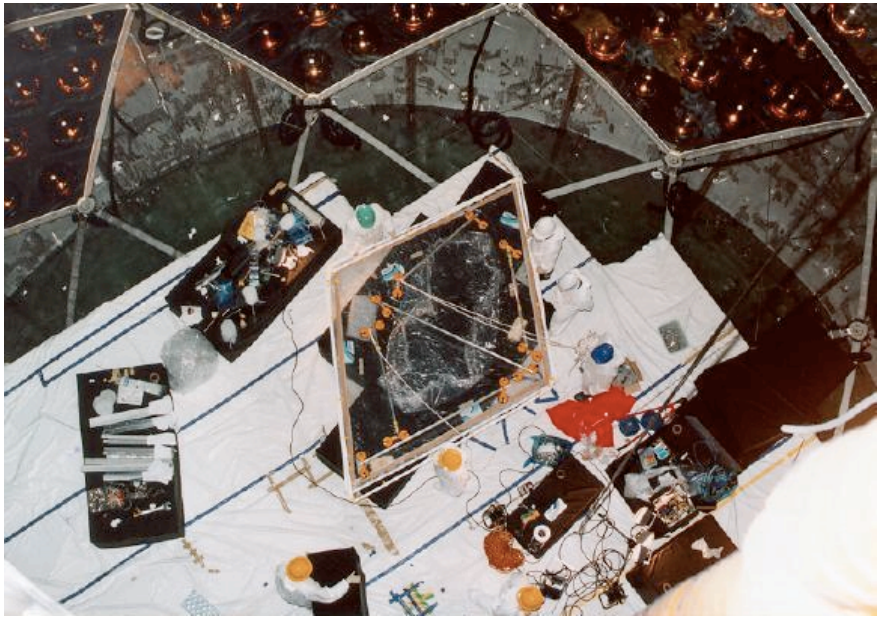
KamLAND Construction

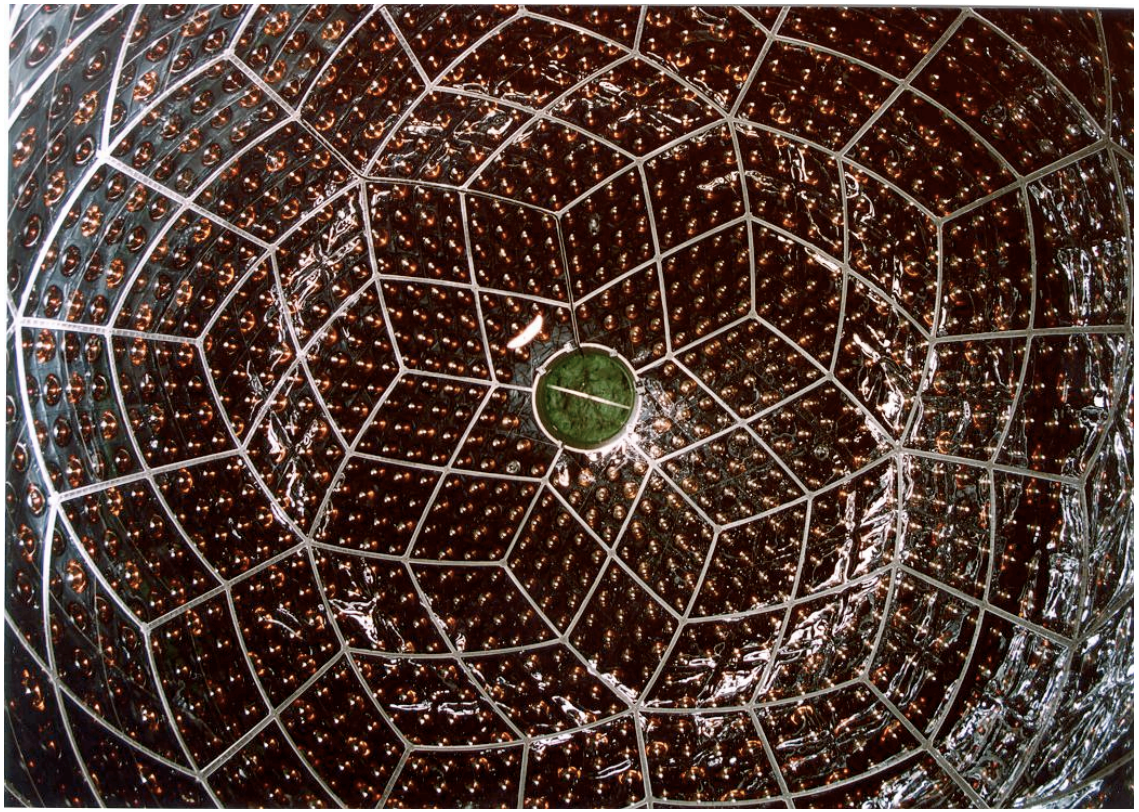


Steel Sphere Constructed
September_October 1999

KamLAND Construction

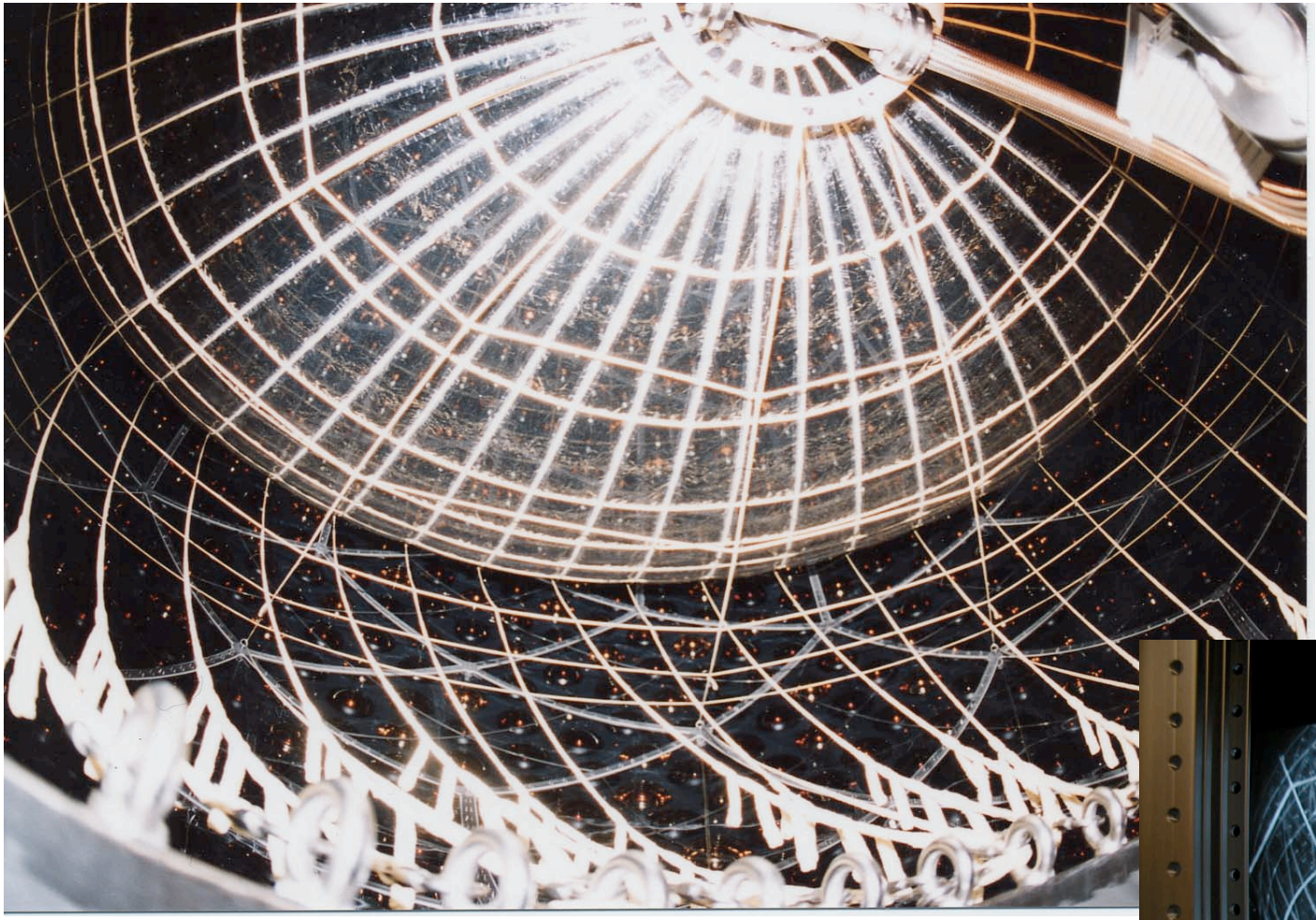


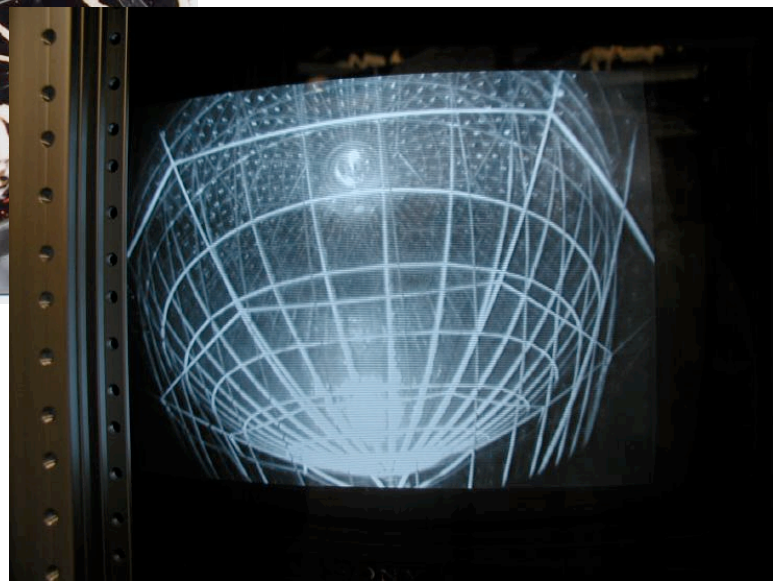




PMT Installation
Summer 2000
Completed September 28

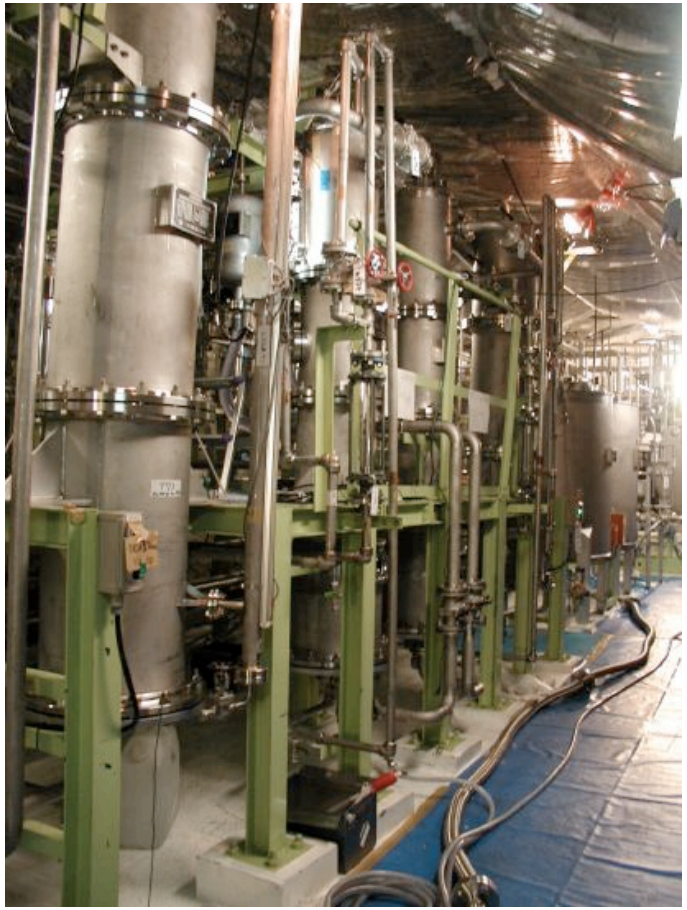
KamLAND Construction

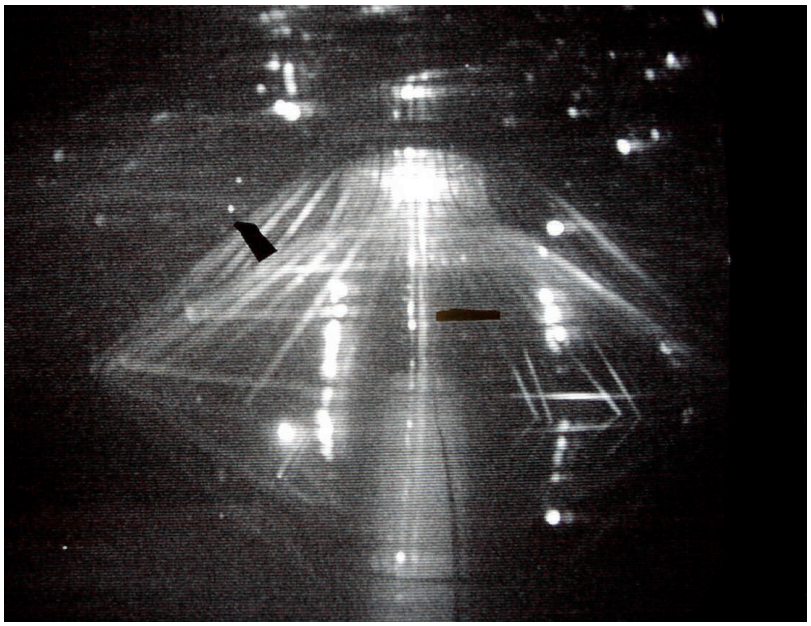




Balloon Installed and Tested
January_March 2001

KamLAND Construction

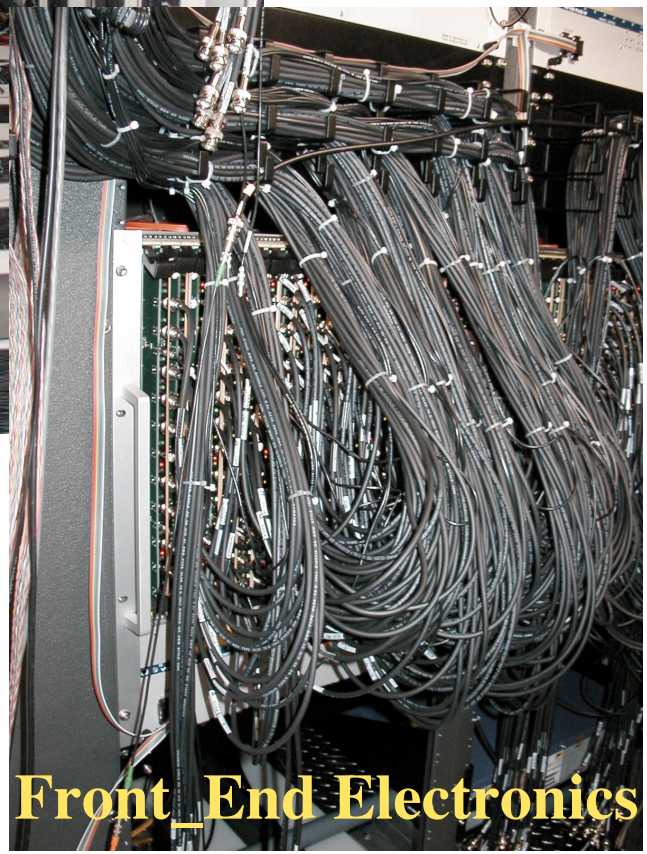


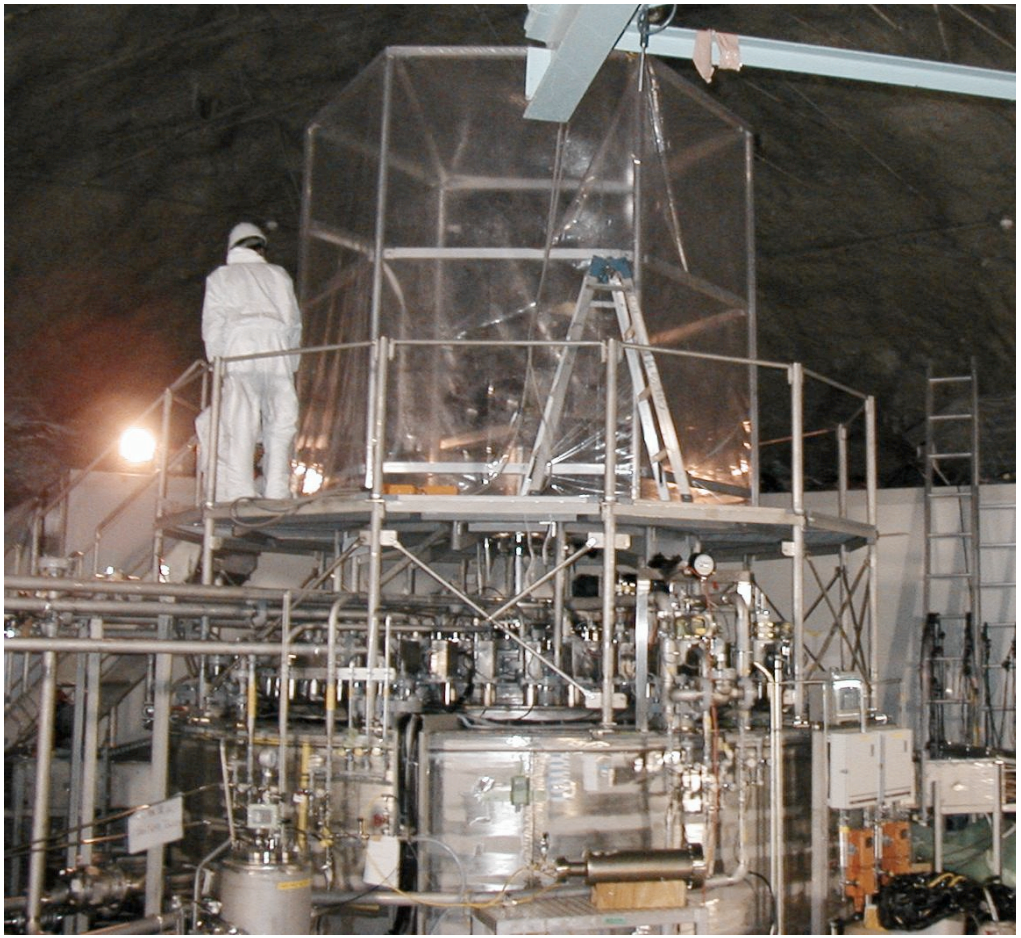


Oil and Scintillator Filling
Spring_Summer 2001
Completed September 24

KamLAND Construction

Infrastructure Completed
January, 2002





Calibration Deck and Glovebox

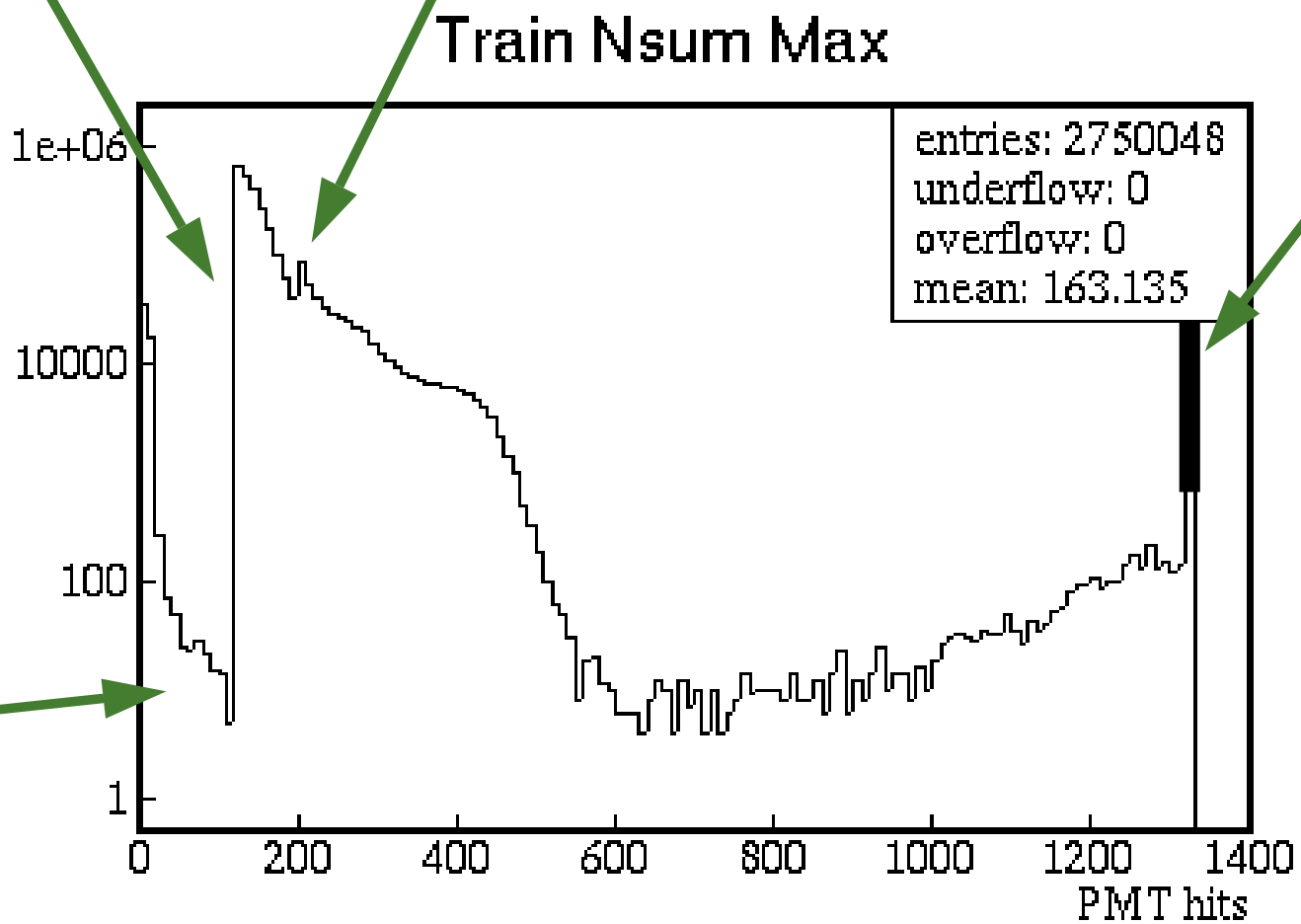
KamLAND Data

Coincidence, prescale, "history" threshold: 120 PMT's hit

Singles threshold: 200 PMT's hit

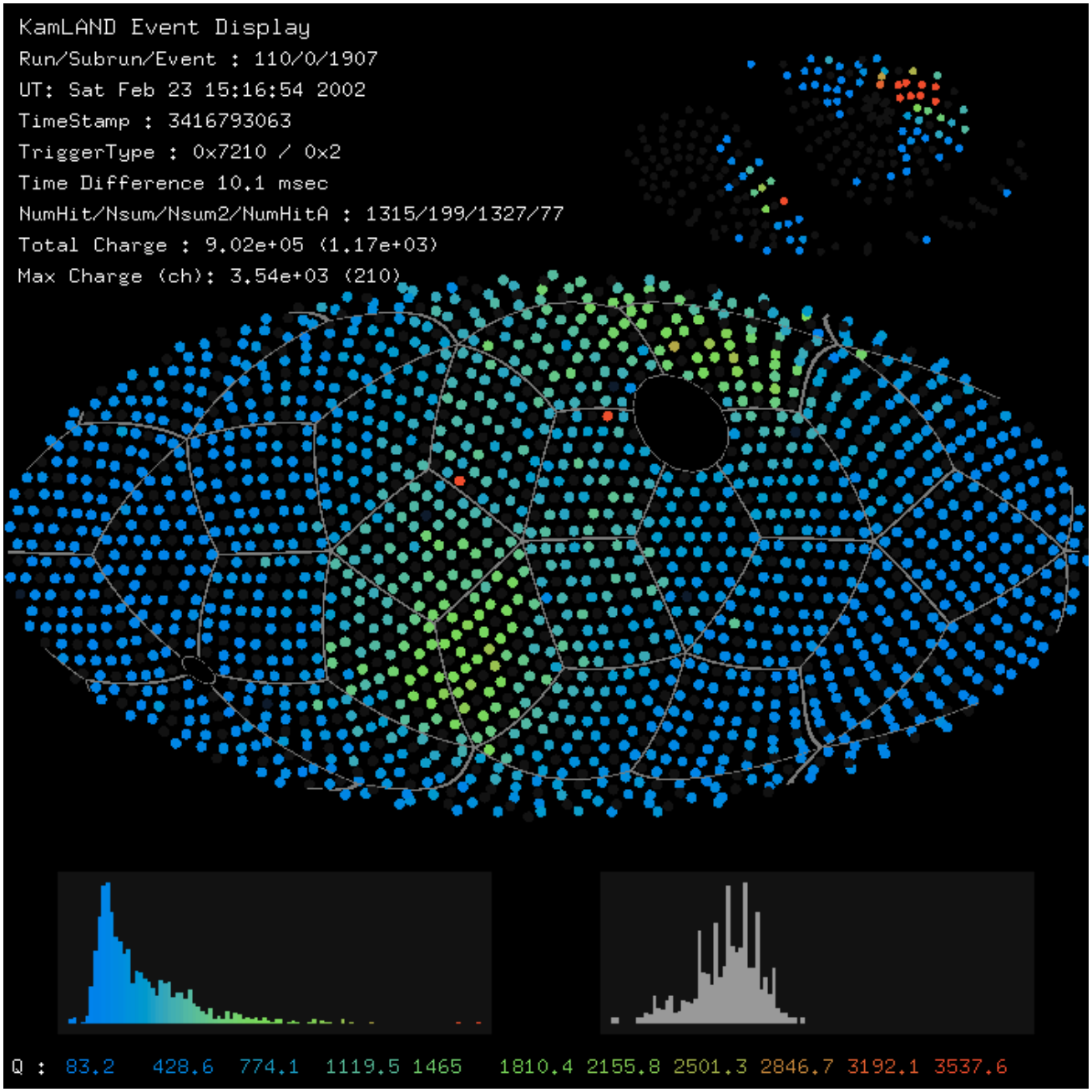
Muons: all tubes hit

Calibration triggers



KamLAND Data Collection Started January 22, 2002

KamLAND Data

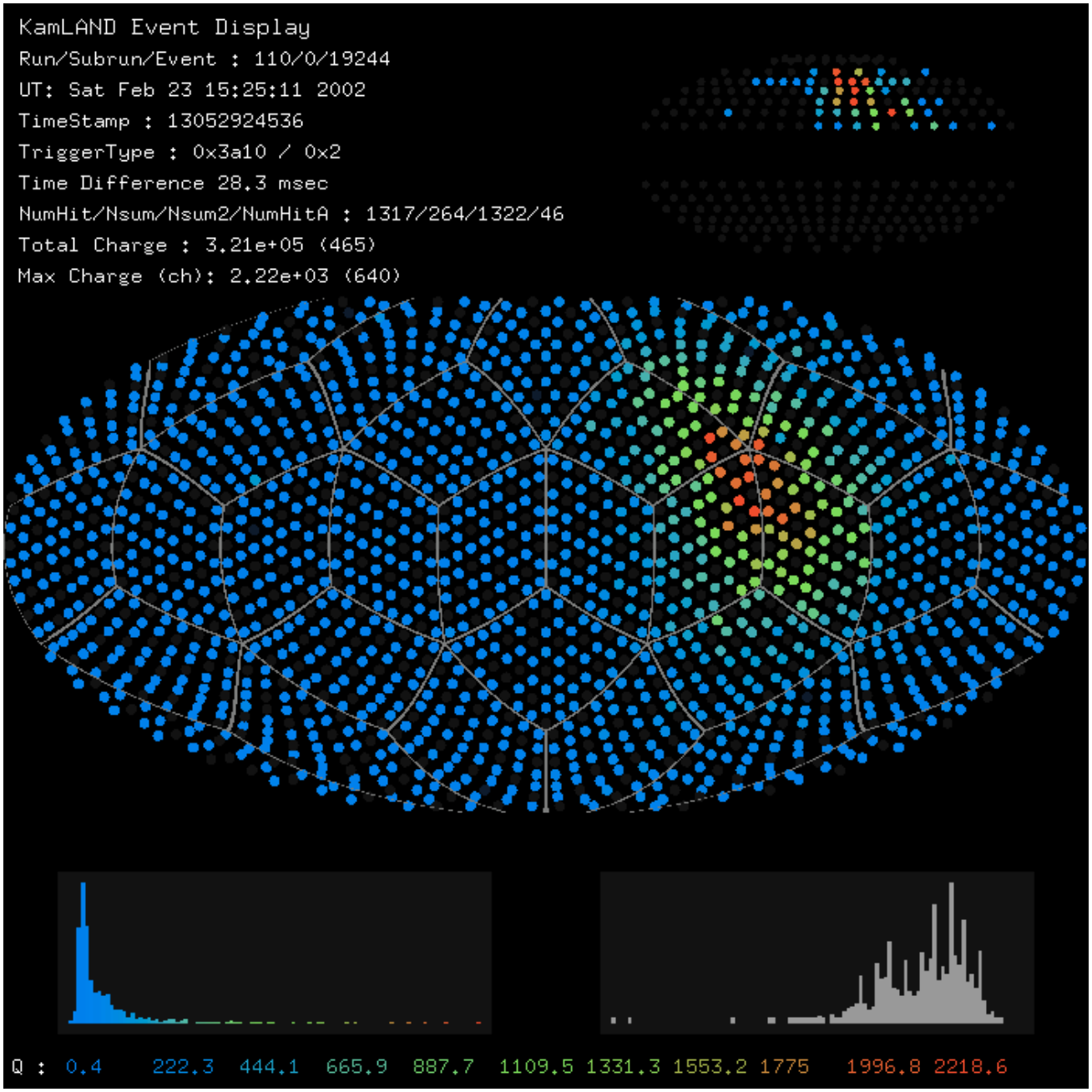


Event Display: through_going cosmic-ray muon

color is pulseheight

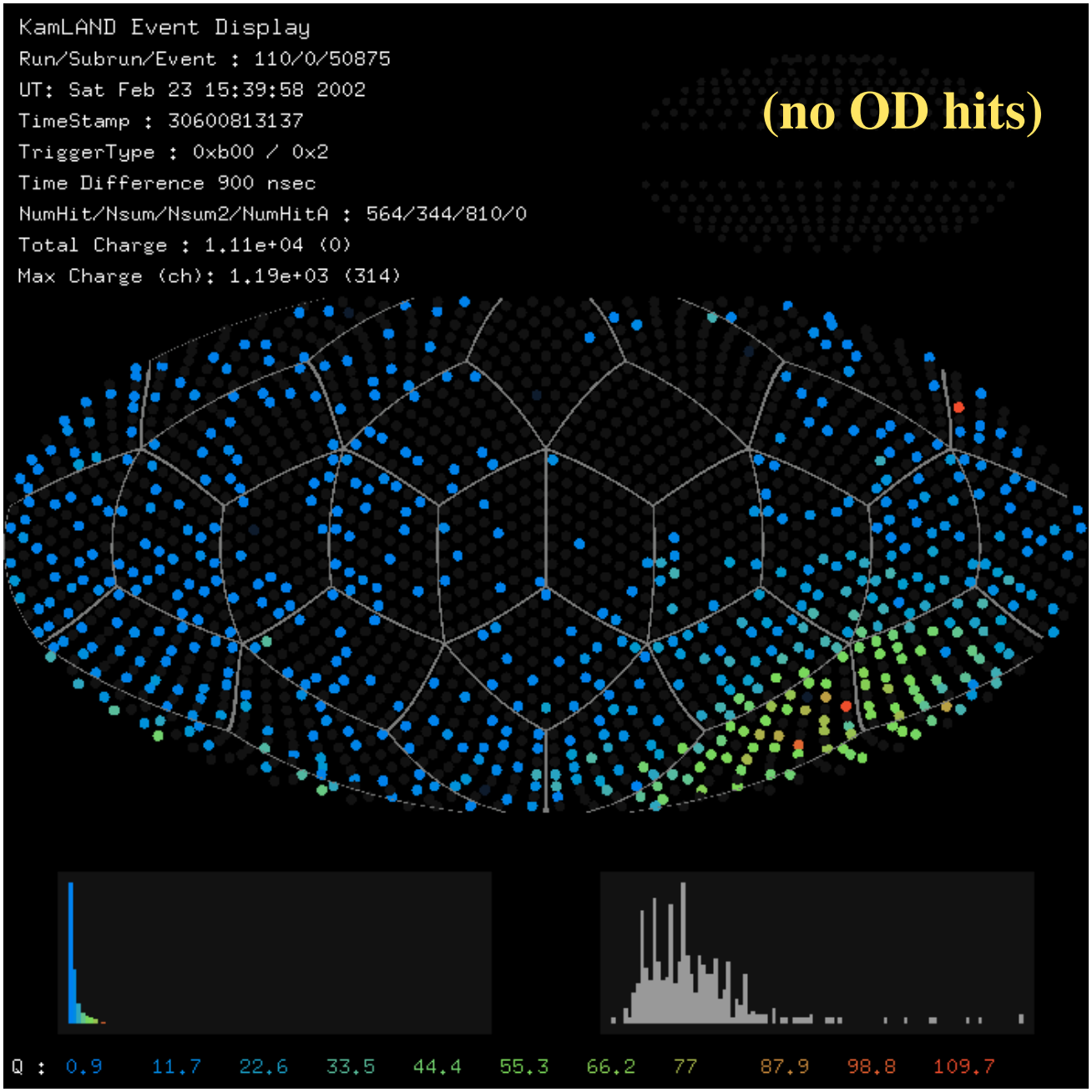
all tubes illuminated

KamLAND Data



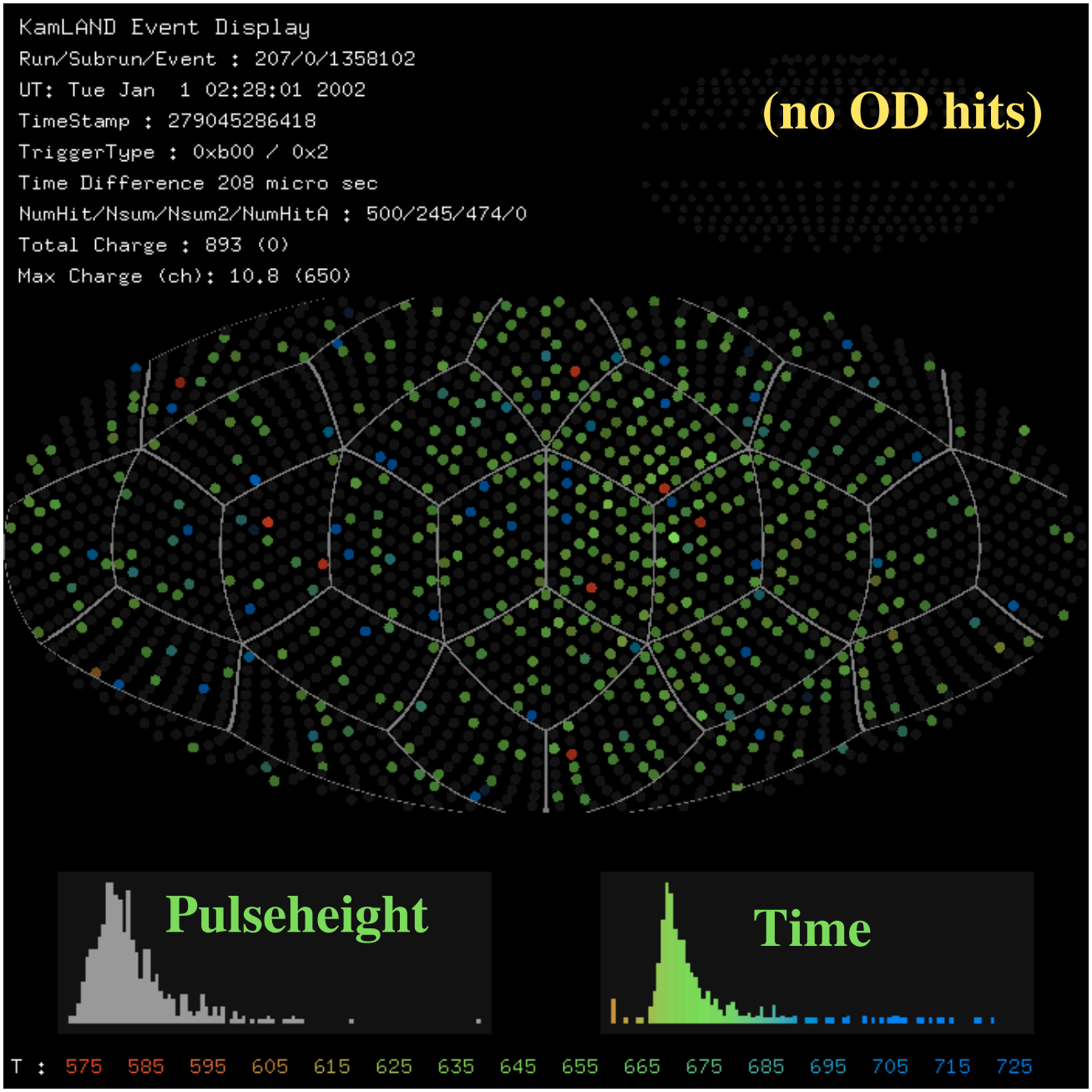
Stopped cosmic-ray muon

KamLAND Data



Medium_energy event: decay electron

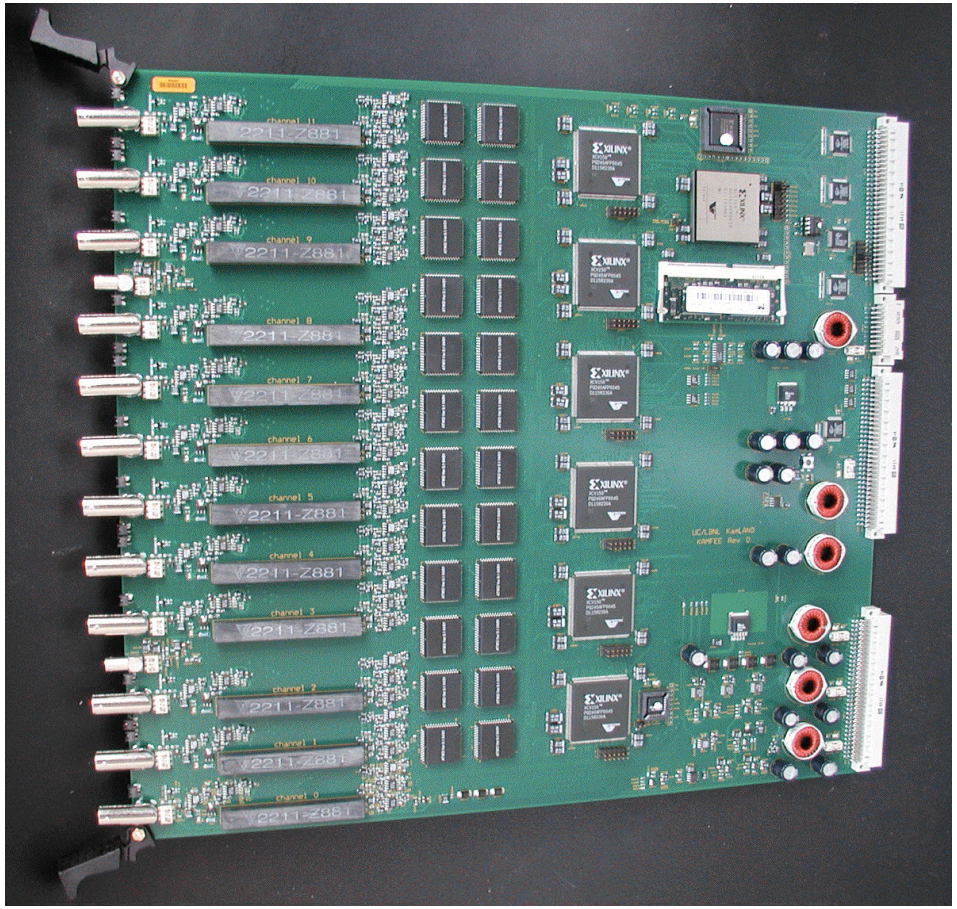
KamLAND Data



Low_energy event (neutrino? background?)

color is time

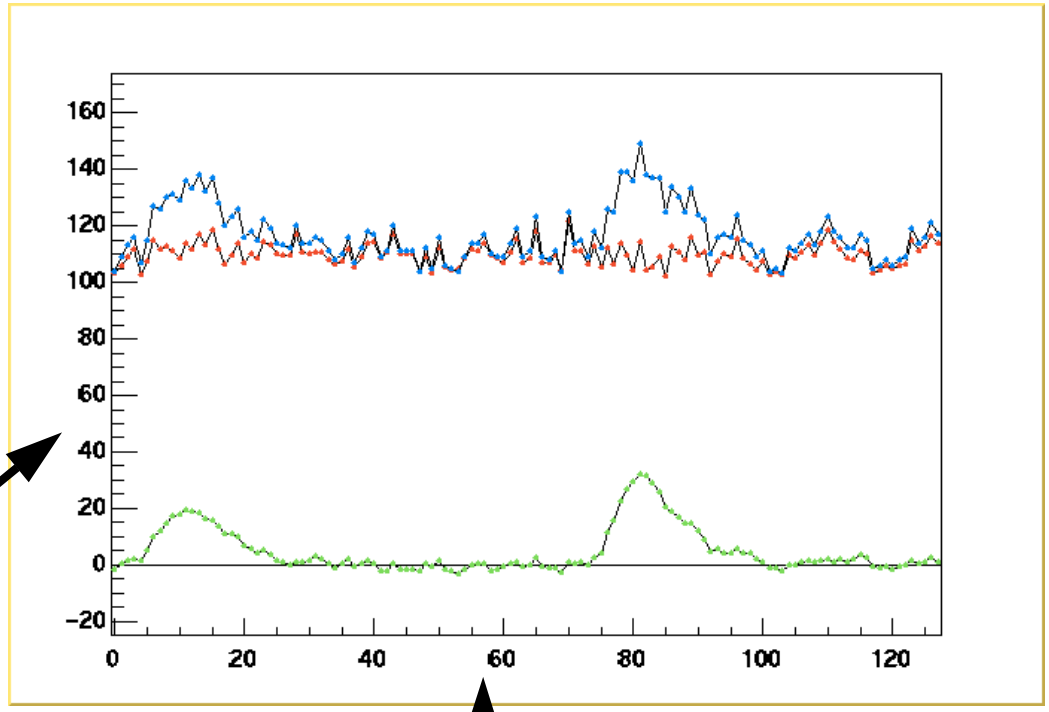
KamLAND Data



12-channel KAMFEE board

The raw data are **waveforms** collected with low-deadtime front_end electronics developed at LBL

Blue: raw data
red: pedestal
green: pedestal subtracted

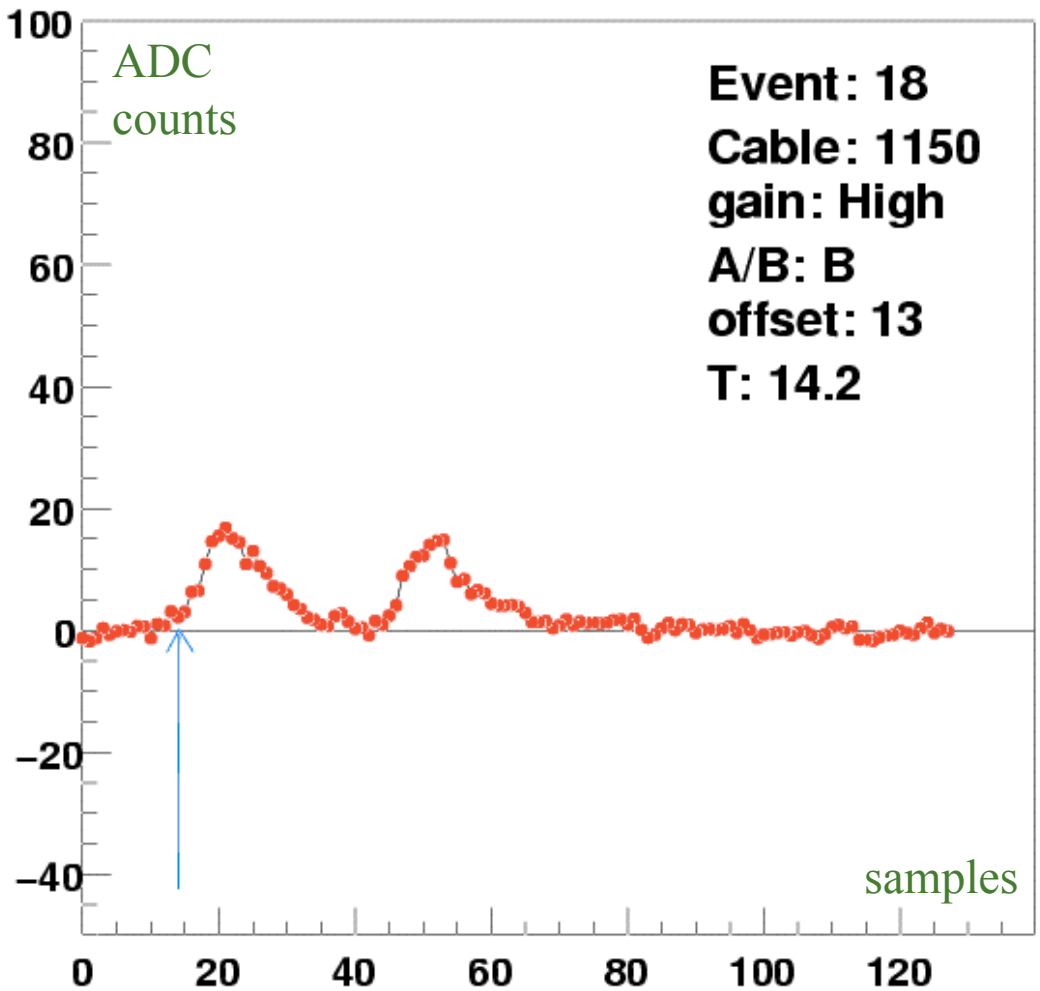


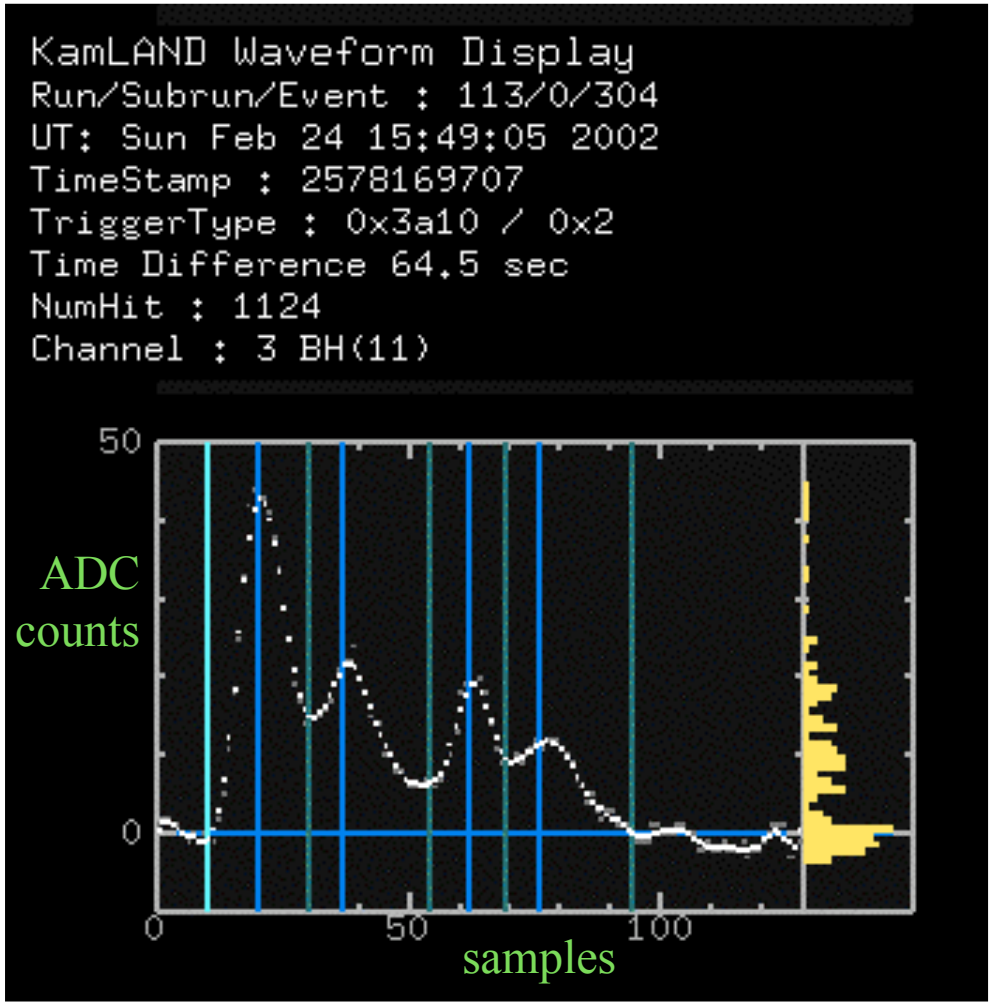
ADC counts (~120 μV)

Samples (~1.5 ns)

KamLAND Data

First step in analysis: convert **waveforms** to **time** and **charge** information





KamLAND Data

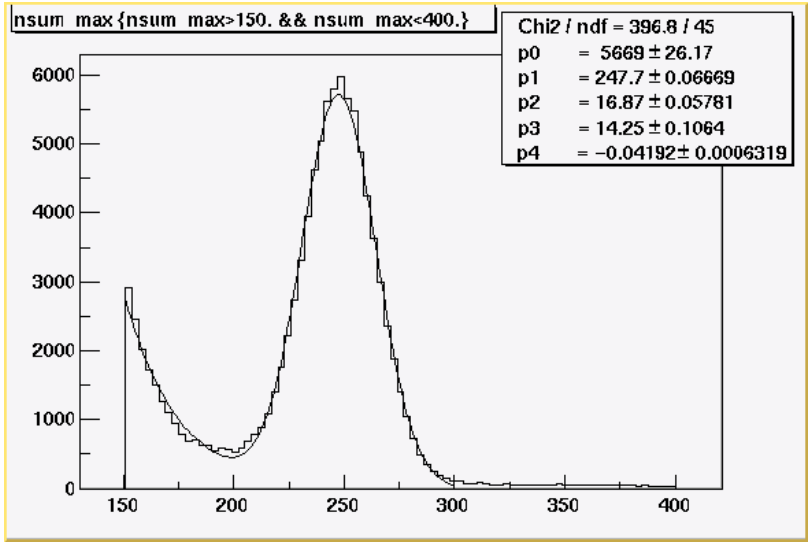
The next step is to convert **time** and **charge** information to event **position** and **energy**

This step requires calibration of the PMT's:

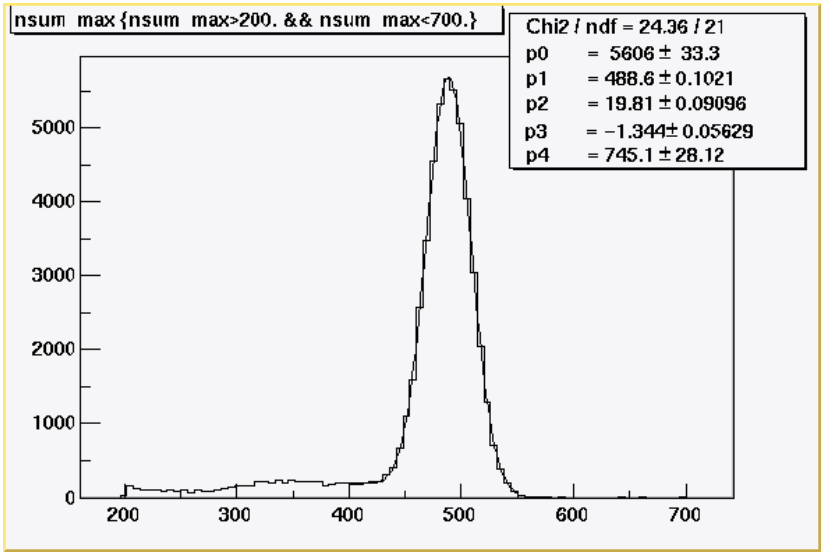
- Timing: done with a blue laser
- Gains: single photoelectron gains with LED's
  high pulseheight gains with UV laser

The detector response as a whole is calibrated with radioactive sources

The **position** is obtained from a **vertex fit**
The **energy** response depends on position



^{65}Zn (1.115 MeV γ)

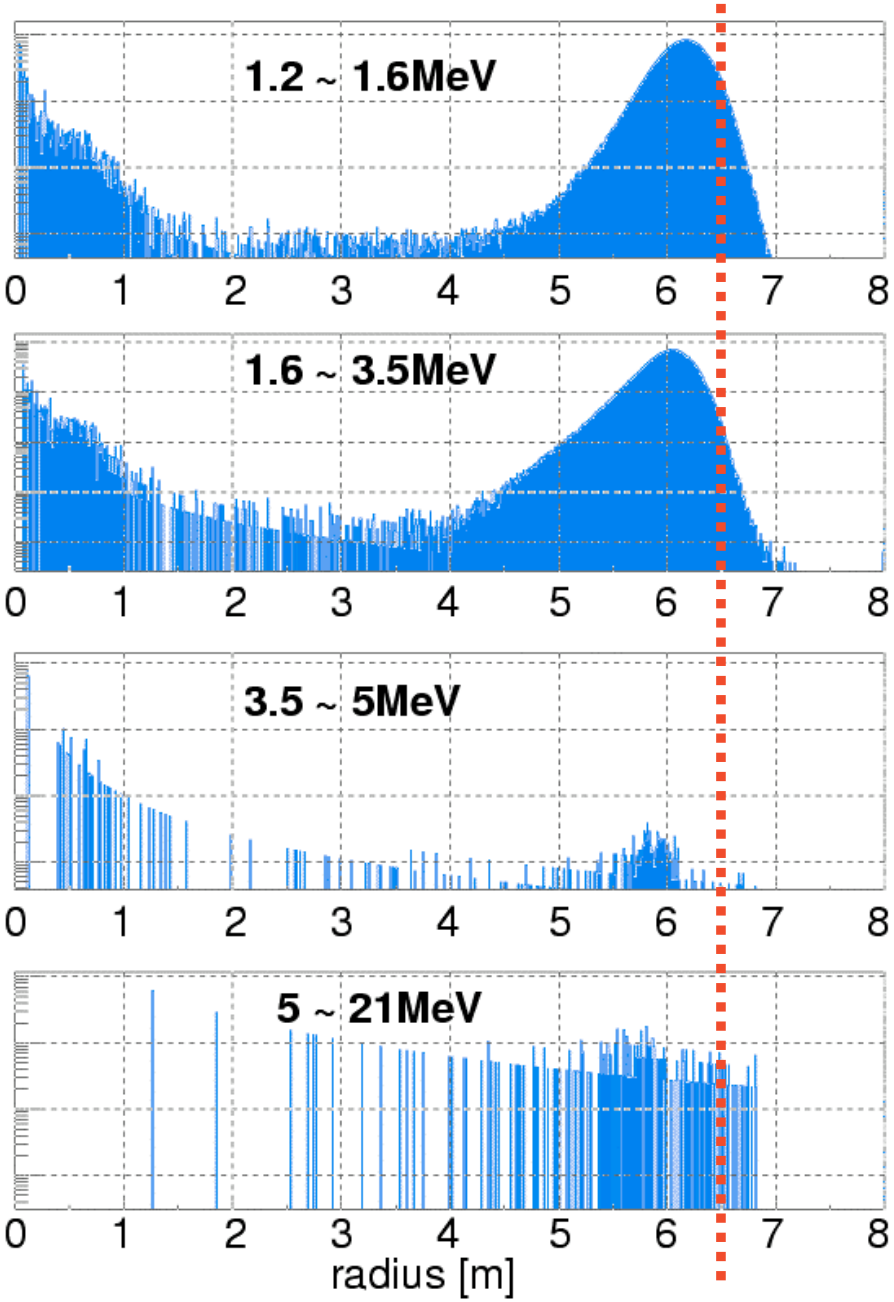


^{60}Co (2.505 MeV γ+γ)

(Note: these are old calibration plots, not valid for current running conditions)

KamLAND Data

Balloon



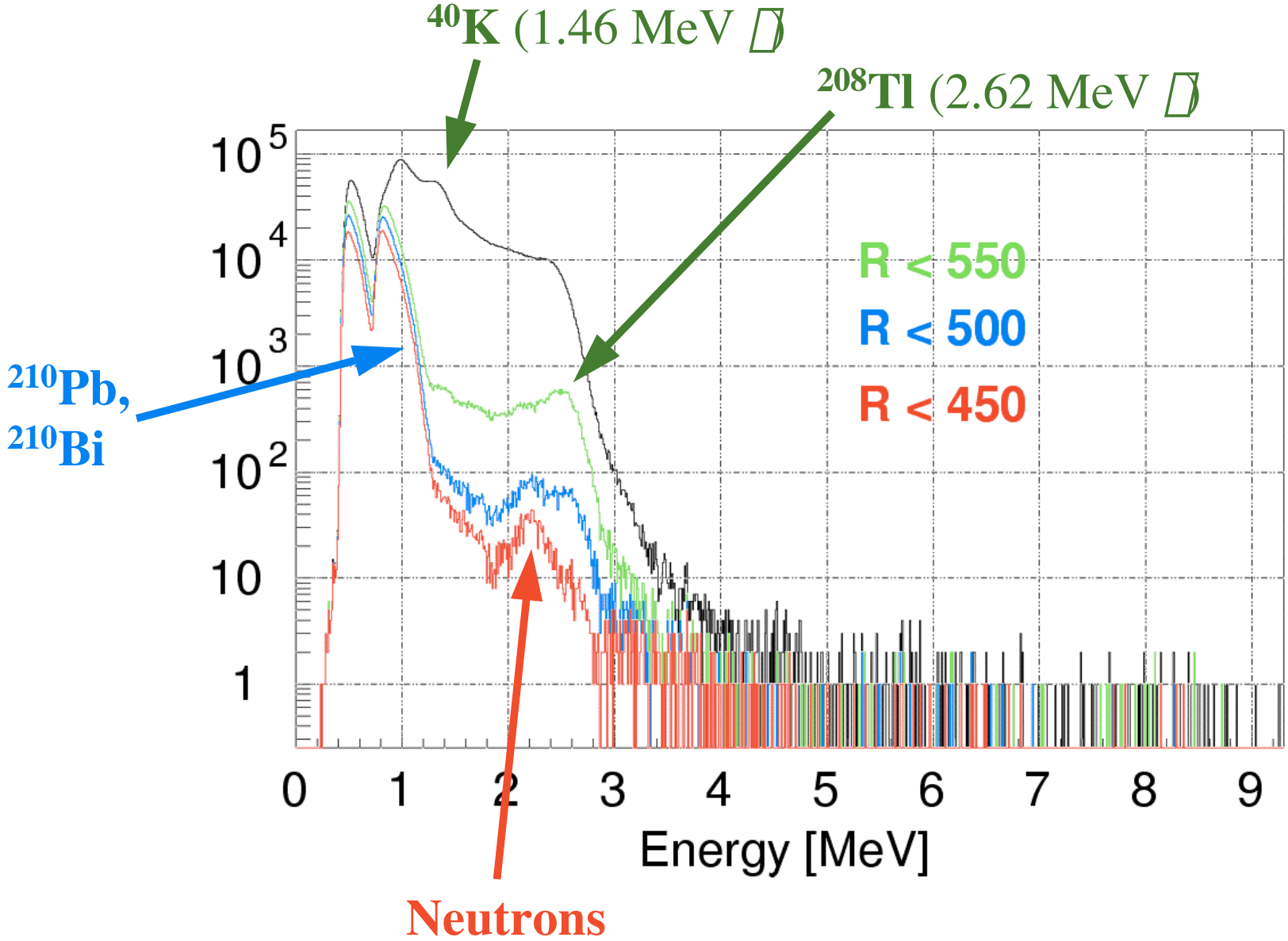
Reconstructed event position for different event energies

$1/R^2$ weight, log scale

Most backgrounds peak near the edge of the scintillator volume

KamLAND Data

Effect of fiducial volume cuts on the energy spectrum



KamLAND Data

Muon_related backgrounds

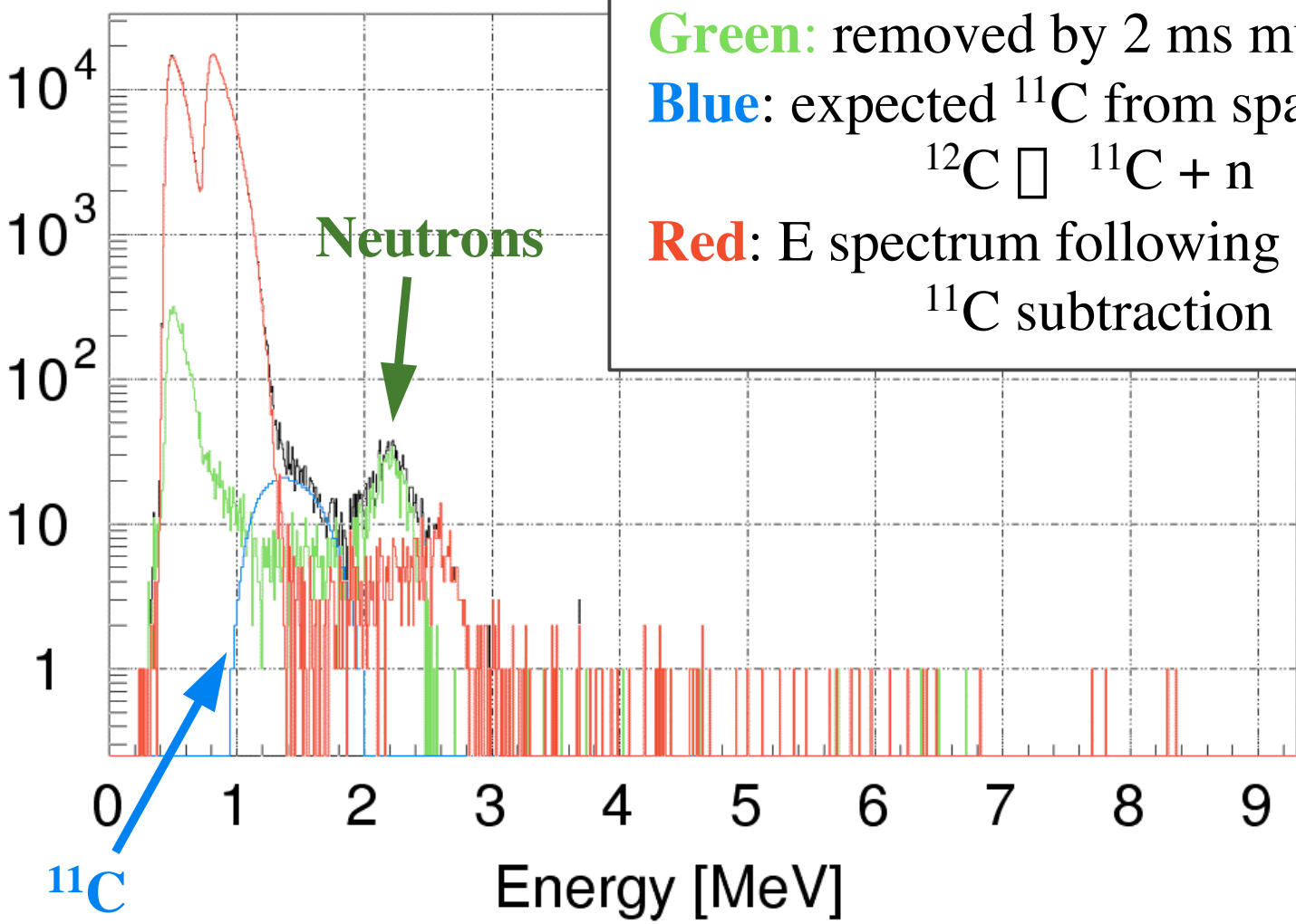
Black: 4.5 m fiducial volume cut

Green: removed by 2 ms muon veto

Blue: expected ^{11}C from spallation:

^{12}C □ $^{11}C + n$

Red: E spectrum following muon veto, ^{11}C subtraction



^{11}C (1.0 MeV □$^+$)

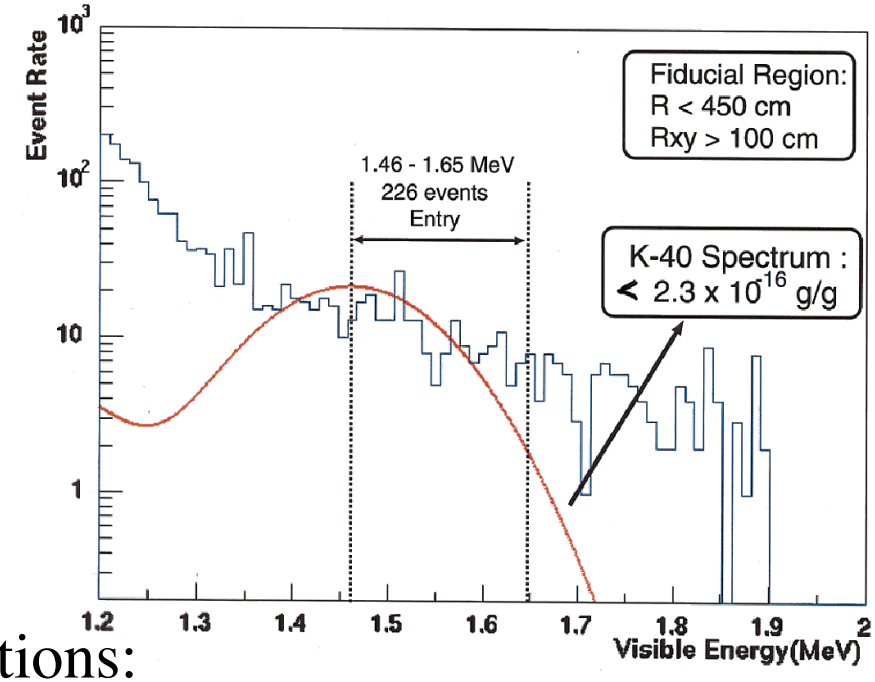
KamLAND Data

Background summary:

- Most backgrounds peak near the balloon
  - radon decay products (^{208}Tl, ^{210}Pb, ^{210}Bi)
  - ^{40}K
- Neutron rate and level of muon spallation products are consistent
- We can also set limits on certain contaminations:

^{238}U	10^{-16} g/g	< 6.4 _ 10^{-16} g/g
^{232}Th	10^{-16} g/g	< 1.8 _ 10^{-16} g/g
^{40}K	10^{-18} g/g	< 2.3 _ 10^{-16} g/g

- Background rates tolerable for reactor experiment
  - Accidental coincidence rate ~0.004 events/day/(5 m fiducial volume)

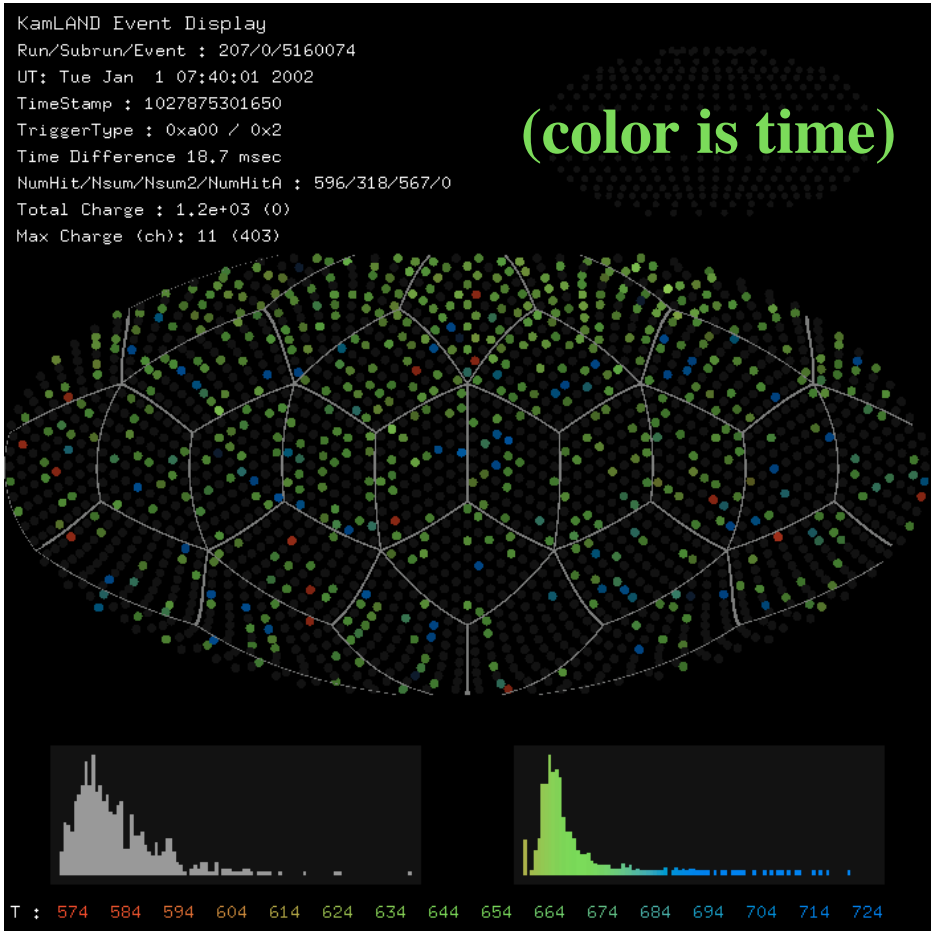


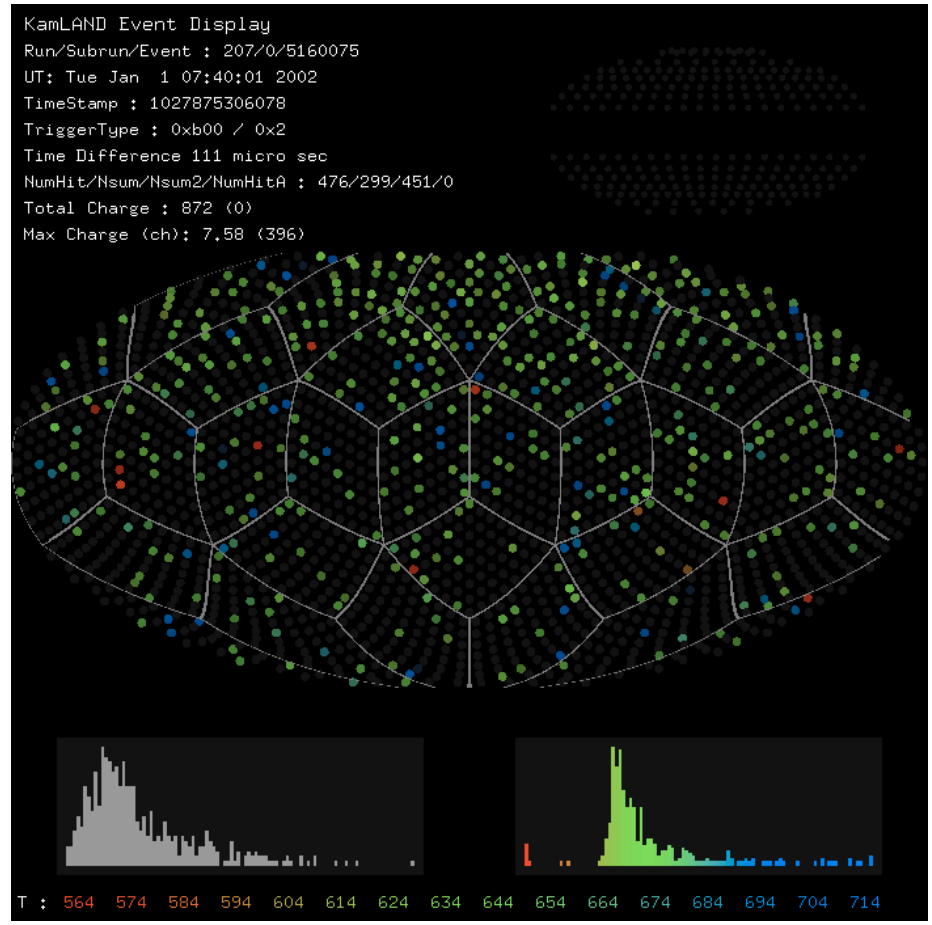
^{40}K limit fit

Now we can add event coincidence and look for neutrinos...

KamLAND Data

Neutrino Candidate





Prompt (e^+) Signal
E = 3.20 MeV

Delayed (neutron) Signal
E = 2.22 MeV

Δt = 111 μs
ΔR = 34 cm

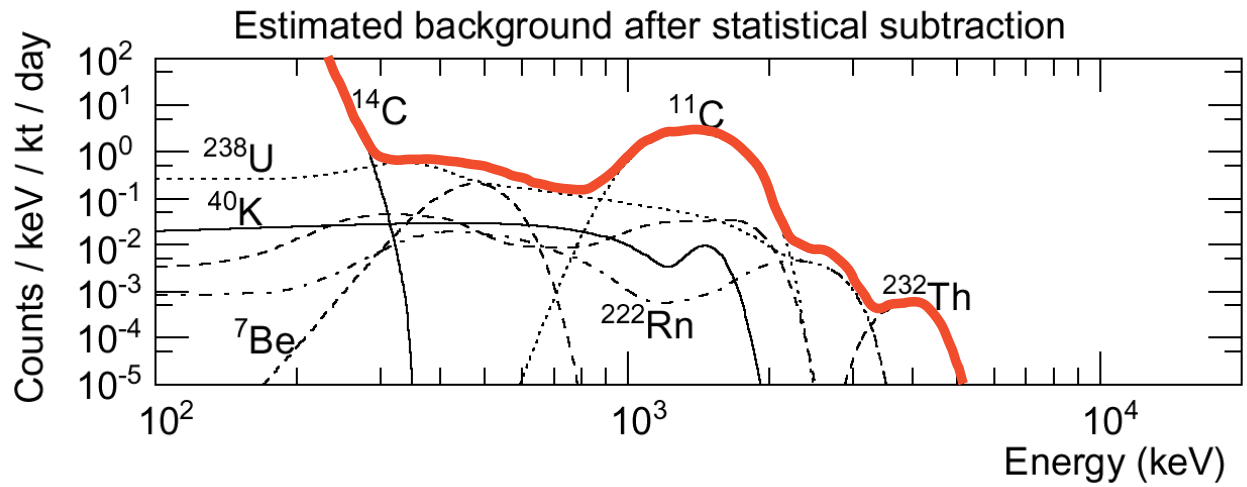
Summary

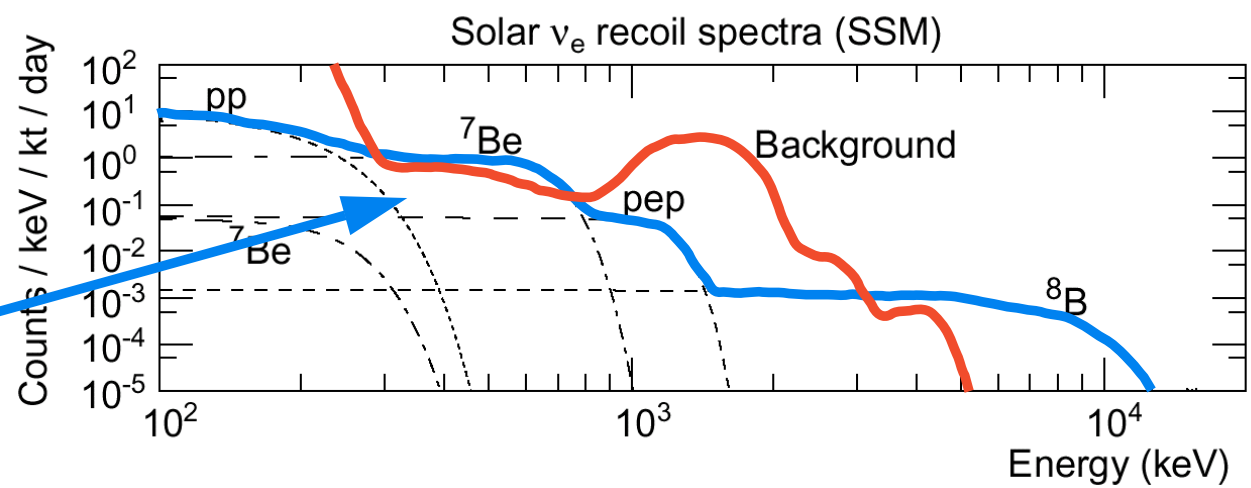
- KamLAND continues to make rapid progress
- Background levels are acceptable for the reactor experiment;
  we are working to reduce them to allow lower NSUM thresholds
- Stay tuned for interesting physics results
- Longer_term future: KamLAND solar neutrino experiment
- For more on KamLAND, go to Nikolai Tolich's talk tomorrow
  Session I15 ("Neutrinos") at 1:21 pm in "Pecos" E209

Solar Neutrinos at KamLAND

- Goal: direct detection of ^{7}Be solar neutrinos
- Singles measurement: no coincidence signal
- Low backgrounds required

(KamLAND proposal*)





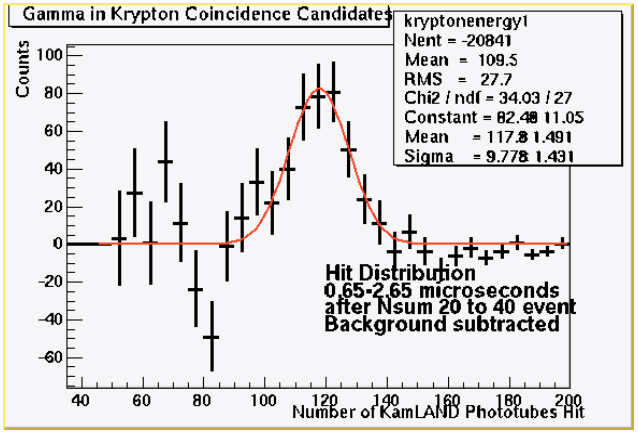
^{7}Be signal

*not our current estimate of low-energy backgrounds!

Solar Neutrinos at KamLAND

- Radiopurity design goals vs. current measurements:

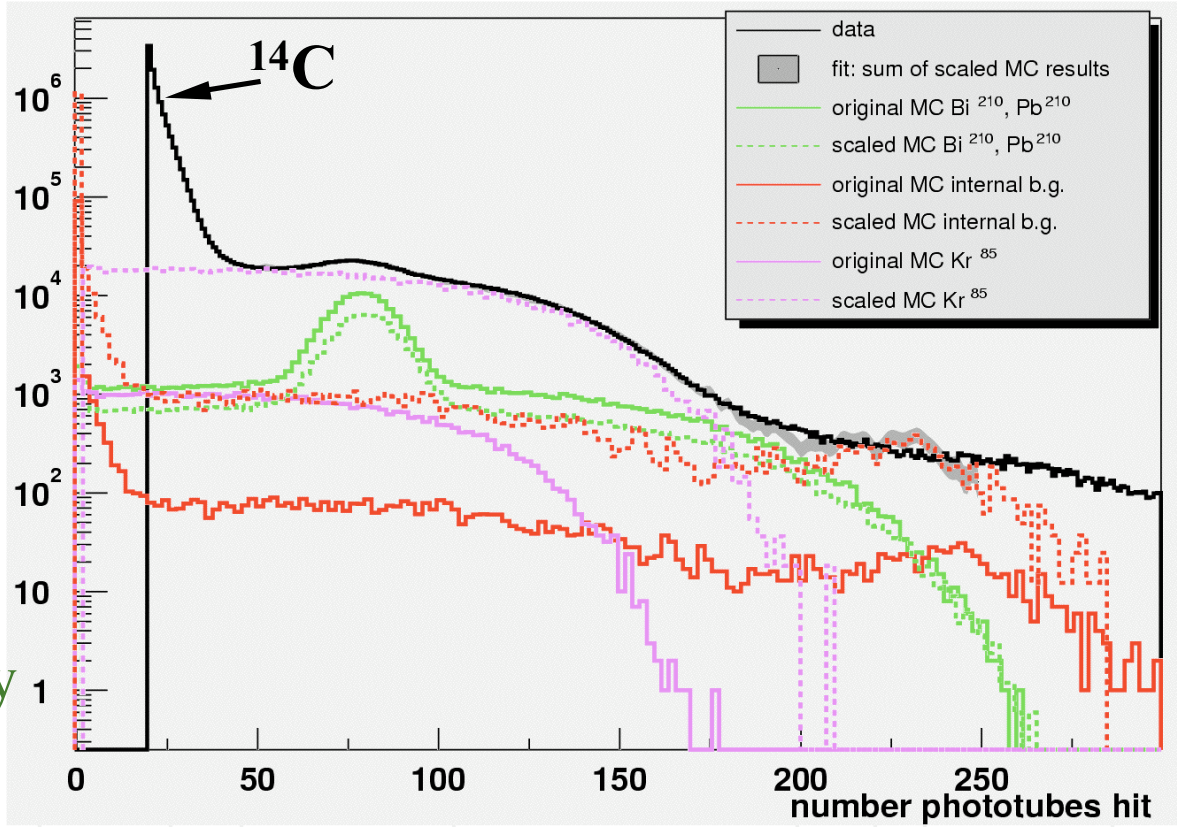
^{238}U	10^{-16} g/g	< 6.4 _ 10^{-16} g/g
^{232}Th	10^{-16} g/g	< 1.8 _ 10^{-16} g/g
^{40}K	10^{-18} g/g	< 2.3 _ 10^{-16} g/g



^{85}Kr coincidence measurement

- Dominant low_energy backgrounds are:
  - ^{85}Kr
  - ^{210}Pb, ^{210}Bi (from Rn decays)

- Working on purification and eliminating leaks to remove such contamination



Observed low_energy event spectrum