Me
Status of Double Chooz
The required pretty picture.

The Double Chooz Collaboration:

APC Paris CNRS/IN2P3, CEA/DSM/ IRFU, SPP, SPhN, SEDU, SIS, SENAC, IPHC Strasbourg, Subatech Nantes, ULB

Aachen U., Hamburg U., MPIK Heidelberg, TU München, EKU Tübingen

CIEMAT Madrid

Sussex U.

INR RAS, IPC RAS, RRC Kurchatov

HIT, Kobe U., Niigata U., Tohoku U., TGU, TIT, TMU

Alabama U., ANL, Chicago U., Columbia U., UC Davis, Drexel U., IIT, Kansas State U., LLNL, MIT, Notre Dame U., Sandia NL, Tennesse U.

CBPF, UNICAMP

Lindley Winslow

I am here thanks to my double chooz colleagues.
Double Chooz is a european-japanese-american-brazilian collaboration of ~150 physicists.

just to orient you as to where I/Double Chooz fit in to the discussions this week.
reactor neutrino experiment

Where in the World is Chooz?

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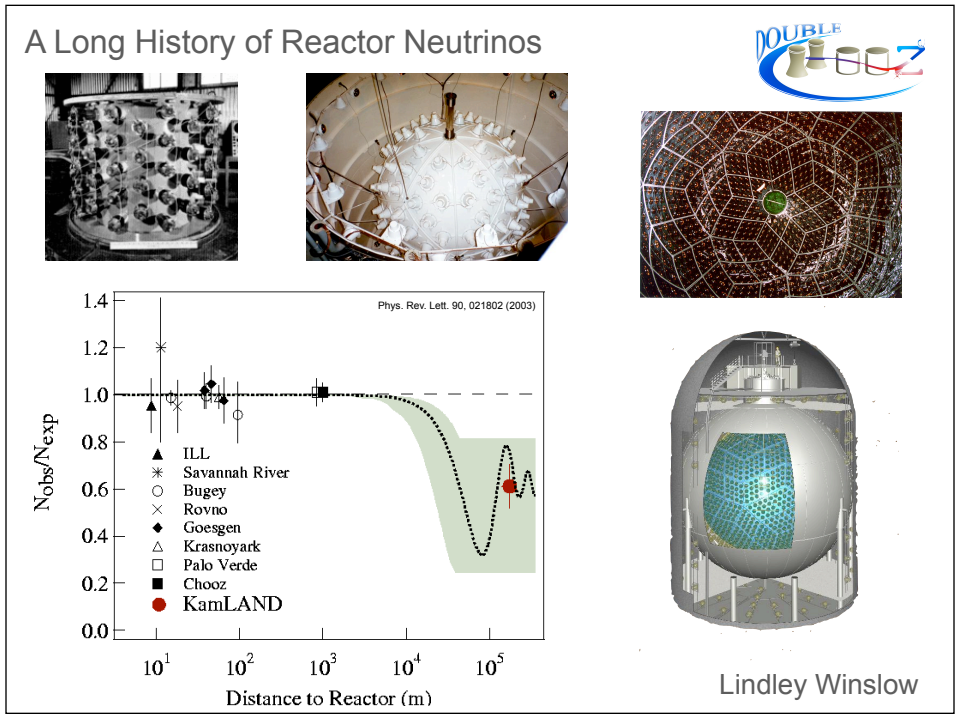
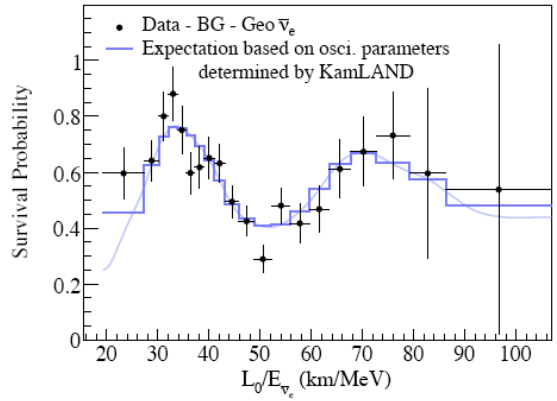
It is located at the border with Belgium.
Fly into Brussels, drive toward Luxembourg and turn right.



The next generation in a long line of reactor neutrino experiments.
Starting from the first detection of the neutrino to the LMA+MSW solution to the solar neutrino problem.
Go through each picture and the plot...

Reactor Neutrinos Oscillating:

Phys. Rev. Lett. 100, 221803 (2008)



$$P_{e,e} = 1 - sin^2 2\theta_{12} sin^2(1.27\Delta m^2_{12} L/E)$$

L_0 is the flux averaged reactor distance, 180 km.

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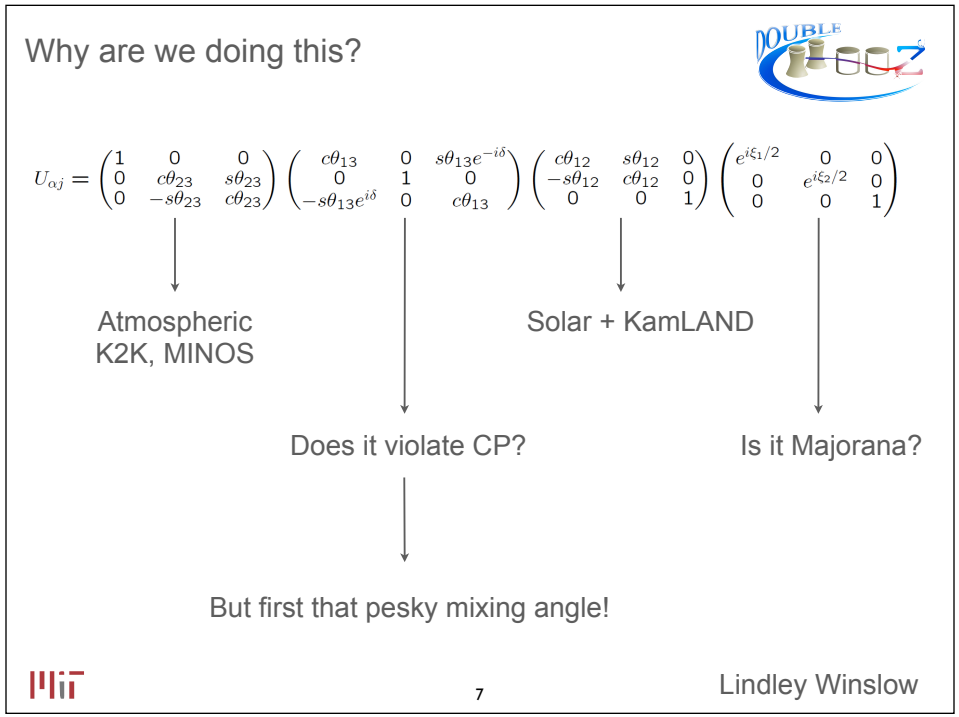
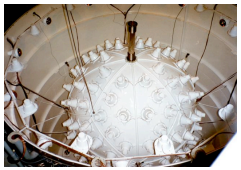
The Beautiful KamLAND plot.
Describe.
Reactors have been good to us.



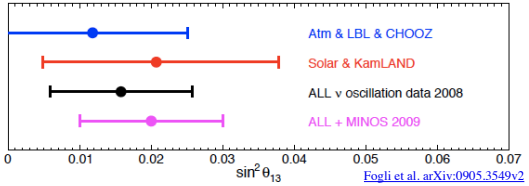
You may have seen this one twice a million times in the last week. Atmospheric Mixing – Majorana phases (Carter Hall/ DBD lectures).
Solar+KamLAND and then the last one, that beautiful CP violating phase that could be evidence for CP violation at higher scales

What are the current best limits?

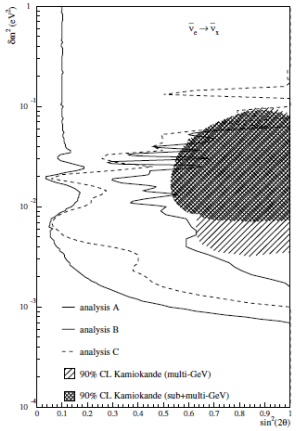


Chooz Bound: $\sin^2 2\theta_{13} < 0.21$

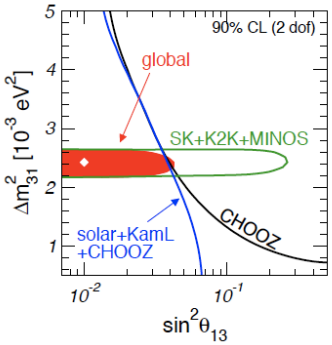
Global Analysis: $\sin^2 2\theta_{13} = 0.04\text{-}0.12$



Fogli et al. arXiv:0905.3549v2



M. Apollonio et. al., Eur.Phys.J. C27 (2003) 331-374



Maltoni and Schwetz arXiv:0812.3161

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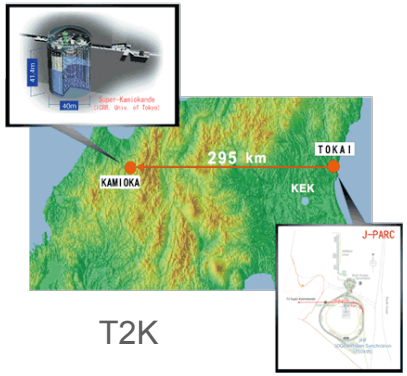
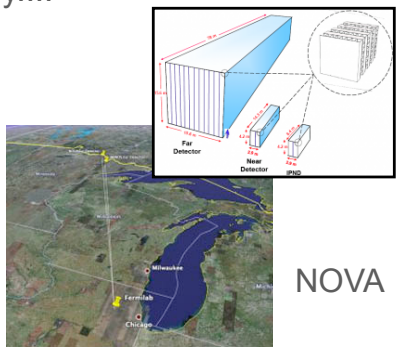
What next?

Long Baseline Does It All:
θ_{13}, CP Violation, Mass Hierarchy....



T2K



NOVA

Unfortunately Long Baseline does it all ...

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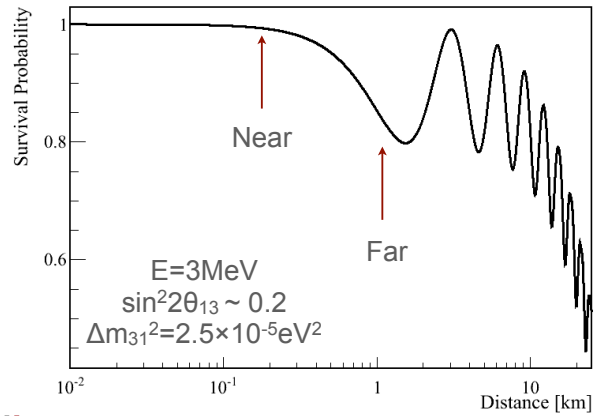
The Most Complicated Formula:

$$P(\bar{\nu}_e \to \bar{\nu}_e) = 1 - \sin^2 2\theta_{13} \sin^2 \frac{\Delta m^2_{31} L}{4E} + \frac{1}{2} \sin^2 \theta_{12} \sin^2 2\theta_{13} \sin^2 \frac{\Delta m^2_{31} L}{2E} \sin^2 \frac{\Delta m^2_{21} L}{2E} - \left(\cos^4 \theta_{13} \sin^2 2\theta_{12} + \sin^2 \theta_{12} \sin^2 2\theta_{13} \cos \frac{\Delta m^2_{31} L}{2E} \right) \sin^2 \frac{\Delta m^2_{21} L}{4E}.$$



Near+Far is key and we will come back to that...
for now reactors provide a very clean measurement.

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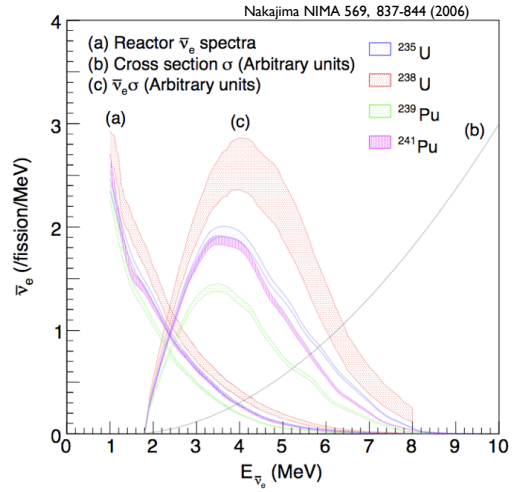
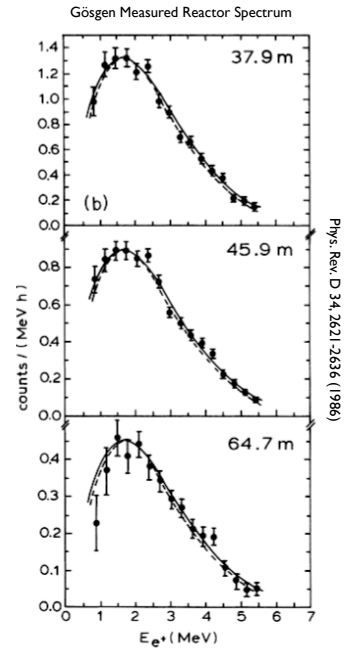
Do you get the joke?

A Few More Details on Reactor Anti-Neutrinos:

- 2×10^{20} anti-neutrinos per s per GW_{th}





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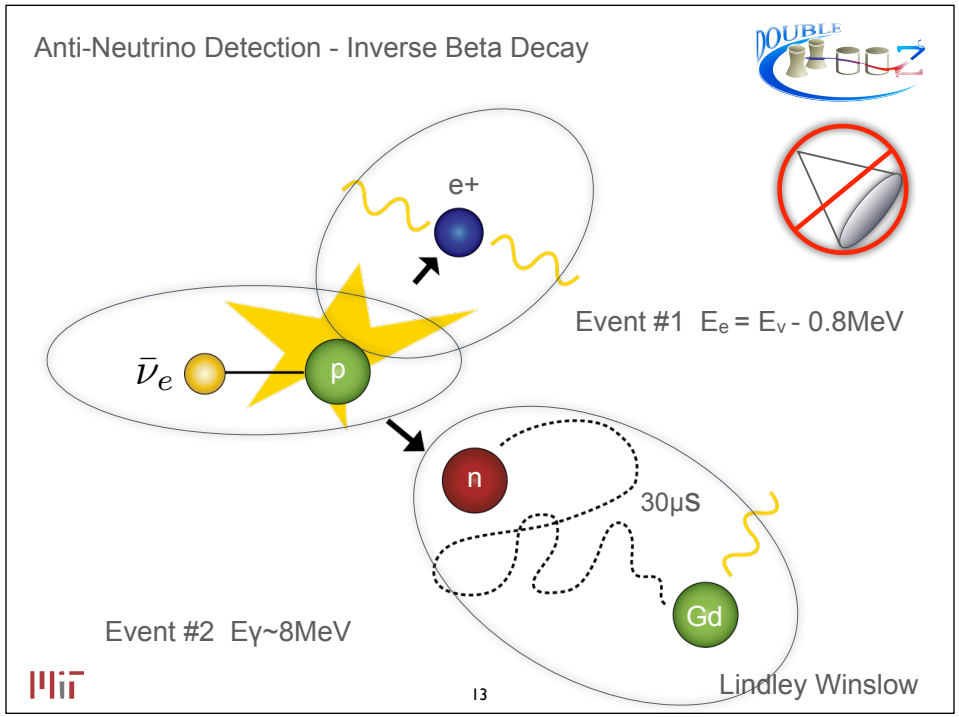
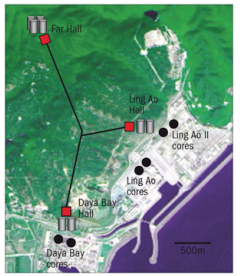
Know how to detect.
What do we expect.
Get the fission data per isotope per day from the 53 japanese reactors.
Cross-sections w/ spectrum gives the expected spectrum.
Measured by all those other experiments see Gosgen....



Most of the spectrum below 5MeV so we are talking about LS not Water C.
Loose directional information.
You can try using the vertex positions but its difficult.
Very low background....

And then there were three:



arXiv:hep-ex/0701029v1 arXiv:1003.1391v1 arXiv:hep-ex/0606025v4

The Three Experiments:

	Double Chooz	Daya Bay	RENO
Reactor Cores	2 Cores	6 Cores	6 Cores
Total Power	8.54 GW	11.6 GW[†]	16.4 GW
Target Mass	8.24 tons	20 tons	15 tons
Near Distance	400m	300-500m[†]	290m
Near Overburden	115 m.w.e	~100 m.w.e[†]	130 m.w.e
Far Distance	1.05km	1.6-1.9km	1.4km
Far Overburden	300 m.w.e.	350 m.w.e	460 m.w.e.
Events per Day	425/43	1600/400[†]	5000/100

[†] Daya Bay will increase to 17.4GW in 2011, has two near sites, and uses multiple detectors per site.

Hunting θ_{13}:

(Disclaimer, all comparisons are of my own imagination and do not reflect the views of my group, collaboration, etc.)

$\sin^2 2\theta_{13} \sim 0.01$

$\sin^2 2\theta_{13} \sim 0.02$

$\sin^2 2\theta_{13} \sim 0.03$

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Why the two detectors?

		Chooz	Double Chooz
Reactor	ν flux and spectrum	1.9%	<0.1%
	Reactor Power	0.7-2%	<0.1%
Detector	Solid Angle	0.3%	<0.1%
	Target Mass	0.3%	0.2%
	Density	0.3%	<0.1%
	H/C and Gd ratio	1.2%	<0.2%
	Spatial Effects	1.0%	<0.1%
	Live time	-	<0.2%
Analysis	From 3-7 cuts.	1.5%	0.2-0.3%
	Total	2.7%	<0.6%

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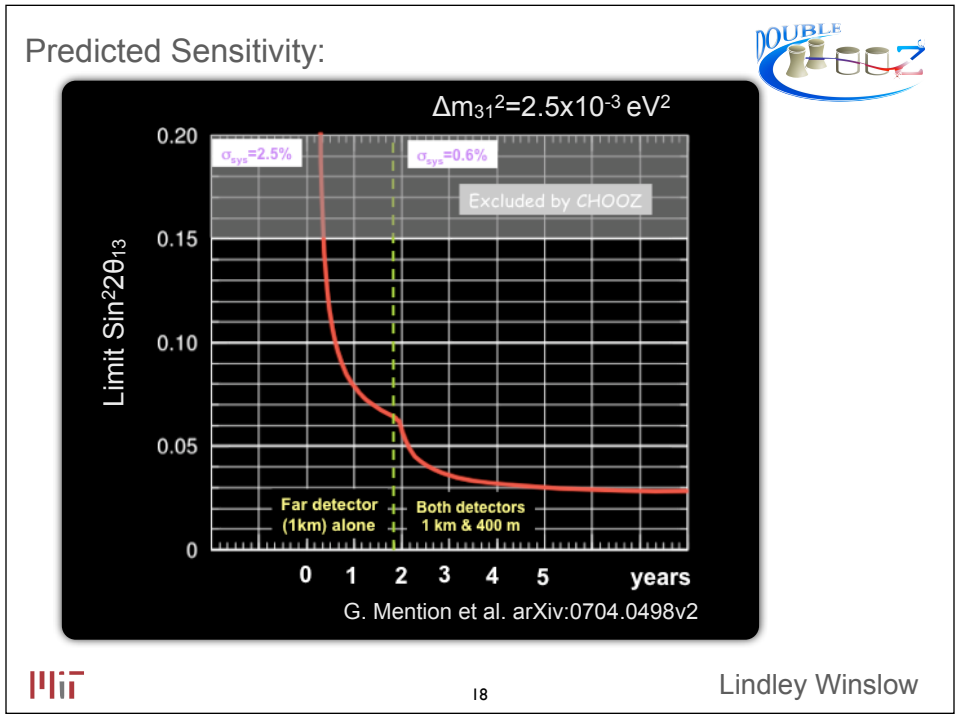
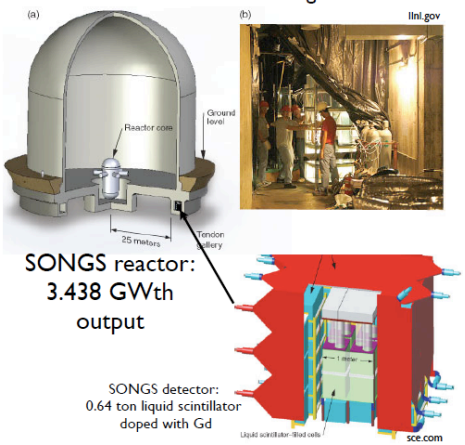
Cancel Systematics -> It is much easier to quantify the difference between
two detectors than to
Especially the reactor systematics - dependent on the electric company.



Far detector alone reactor systematics
Both detectors – dominated by the differences between the two detectors.

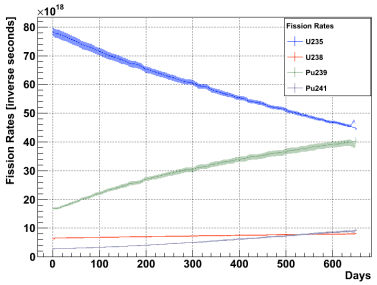
Using SONGs Data to Verify Reactor Models:

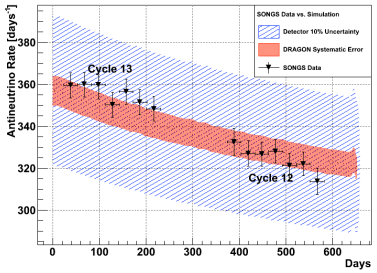
San Onofre Nuclear Generating Station



SONGS reactor:
3.438 GWth
output

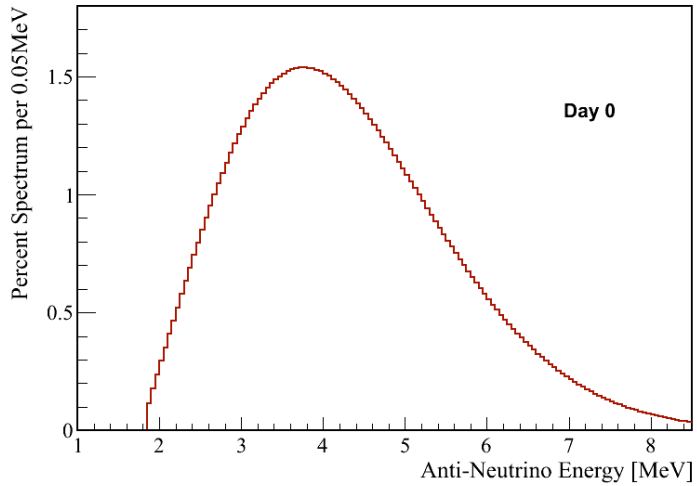
SONGS detector:
0.64 ton liquid scintillator
doped with Gd





Work of C. Jones with LLNL and Sandia NL

Spectral Evolution:



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