Some Ideas on Optimizing a Reactor Based Measurement of θ_{13}

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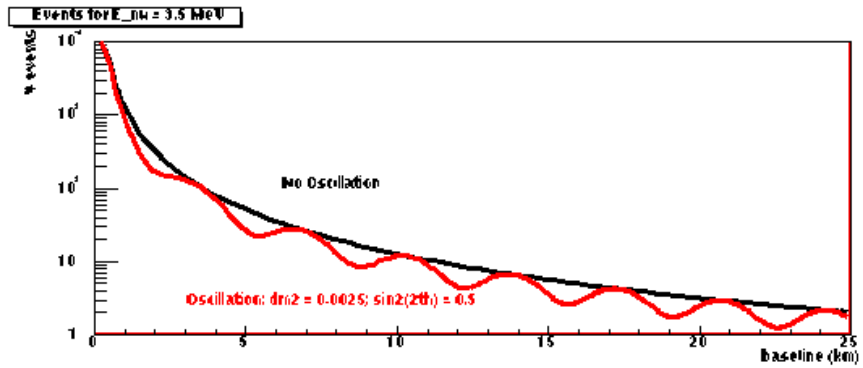
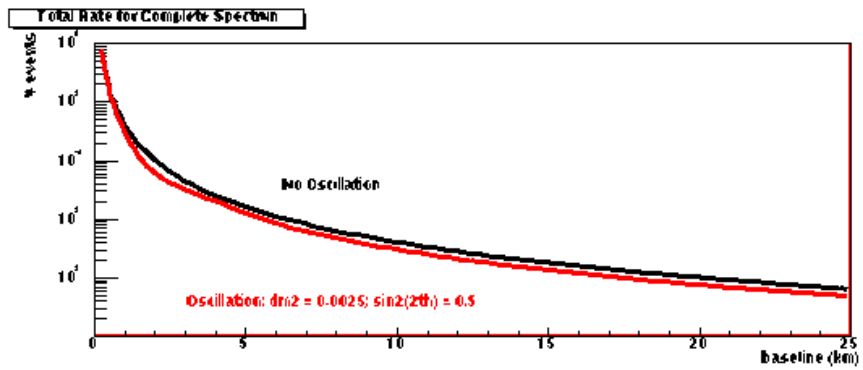
Total Rate vs. Baseline

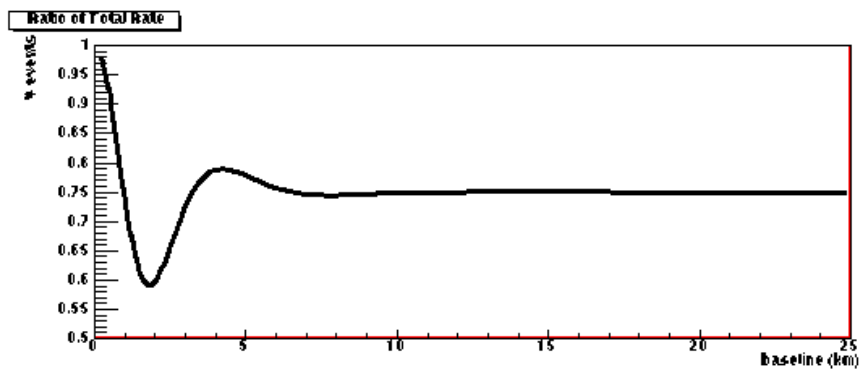
E_ν = 3.5 MeV

$$\Delta m^2 = 0.0025$$
$$\sin^2(2\theta_{13}) = 0.5$$

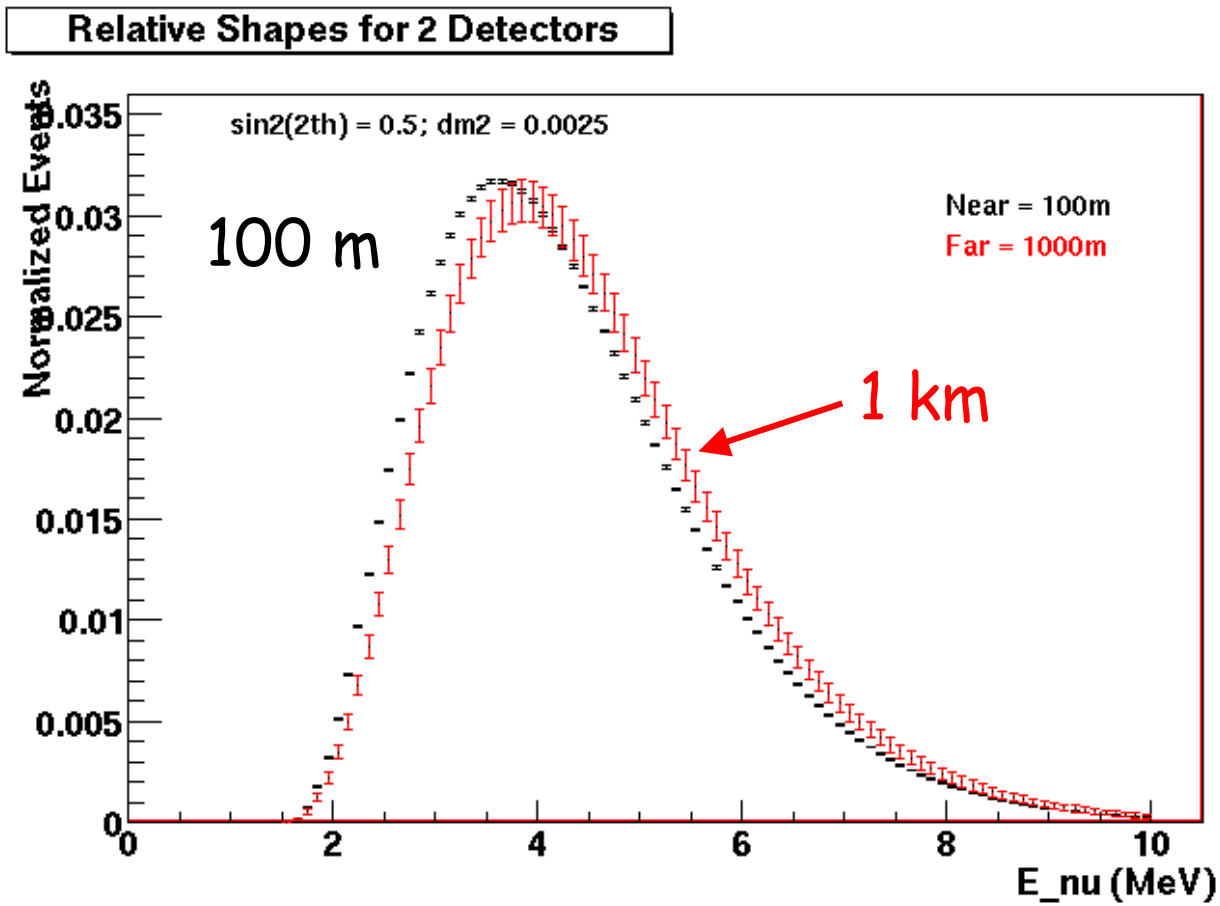
Full Reactor Spectrum







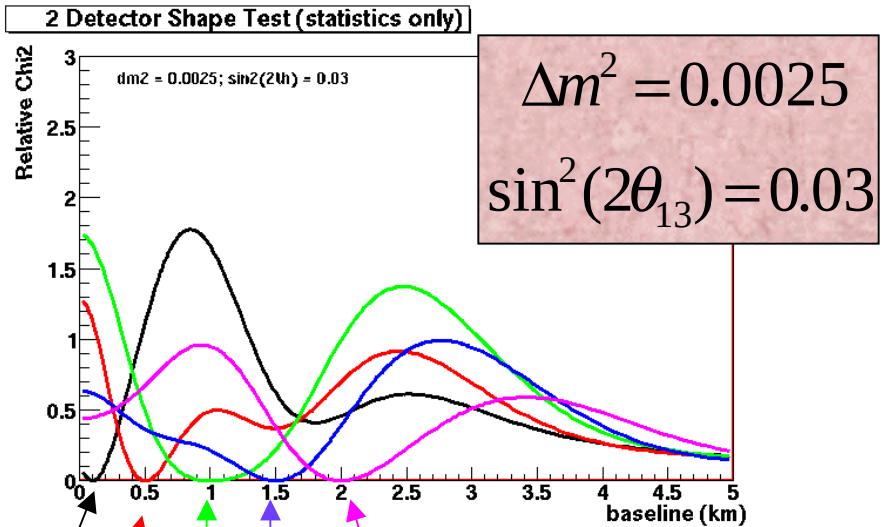
Shape Comparison



Make χ^2 Comparison Of Distributions

- Each bin normalized to total at that location
- Errors are statistical only

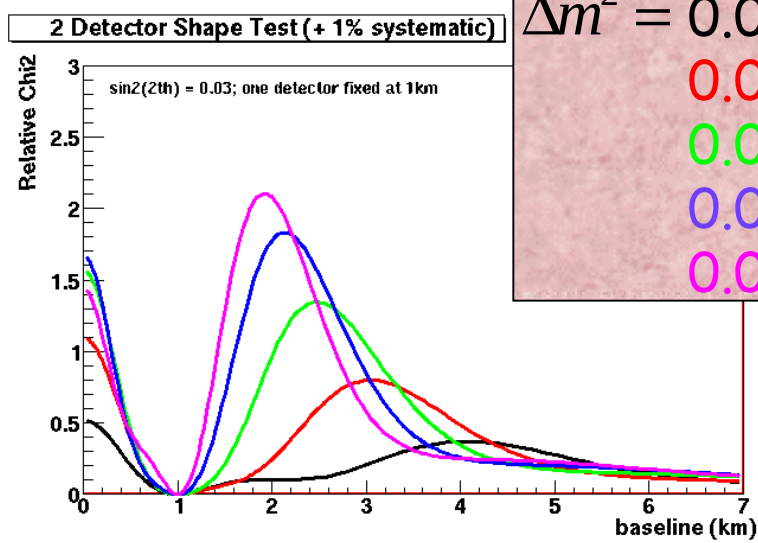
Optimizing 2 Locations



$$\Delta m^2 = 0.0025$$
$$\sin^2(2\theta_{13}) = 0.03$$

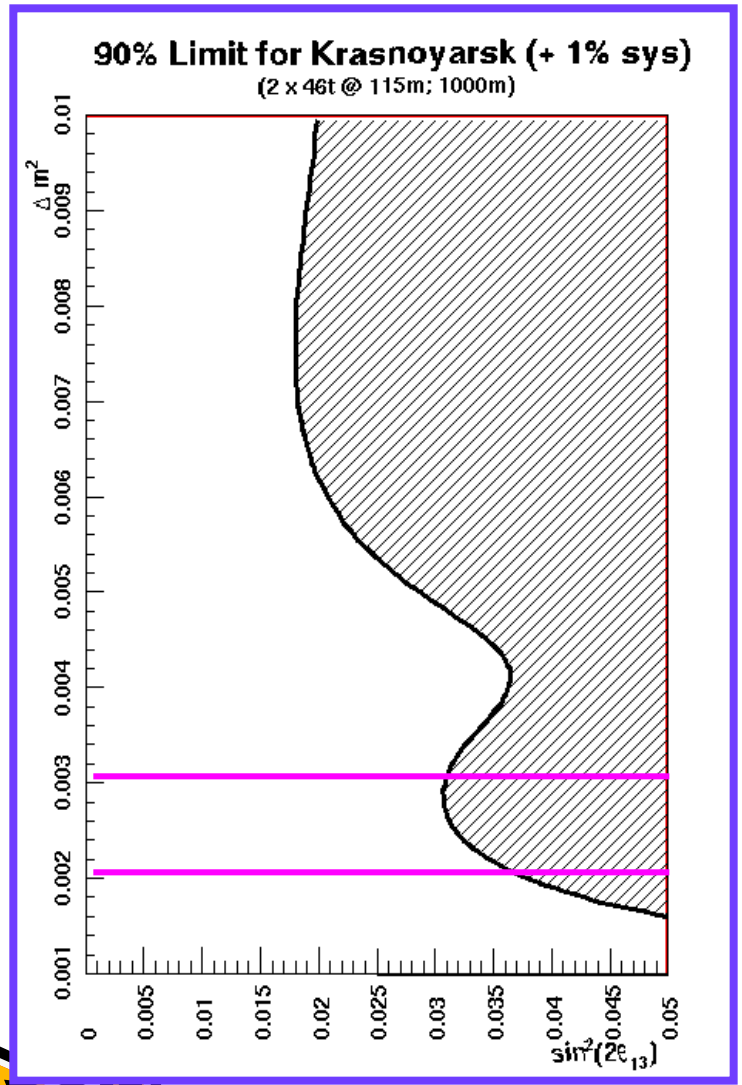
100m
500m
1km
1.5km
2km

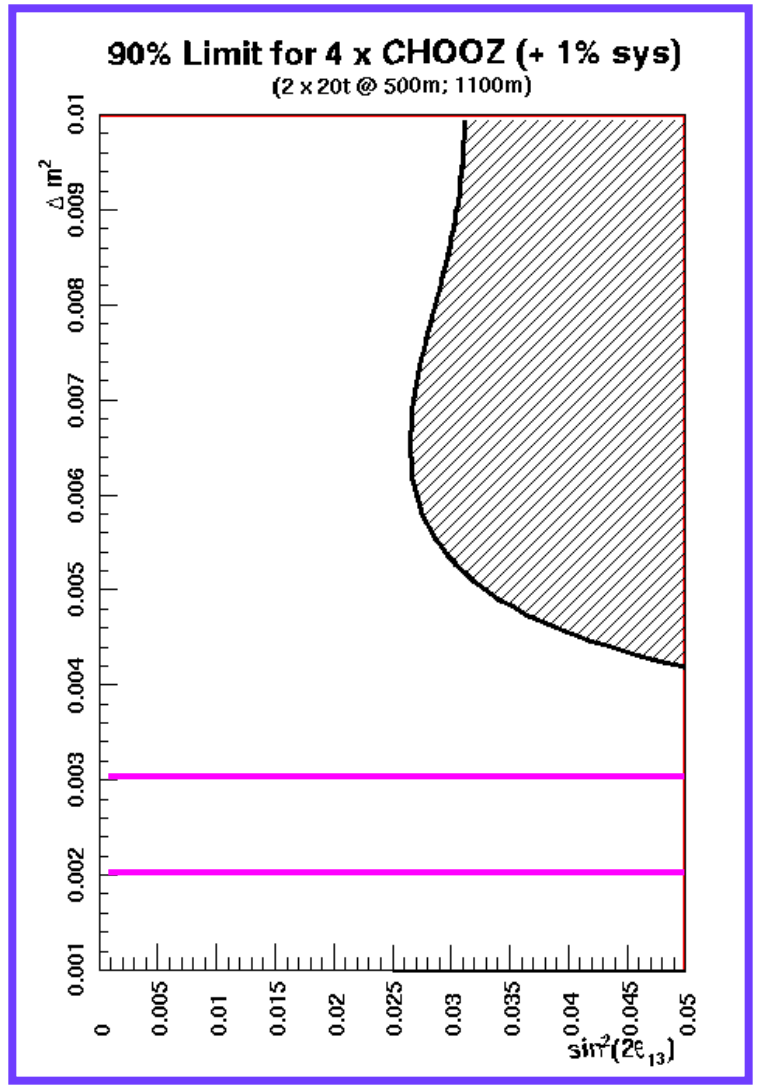
- 2 Identical Detectors
- Fix 1 Detector Baseline
- Sweep the Other

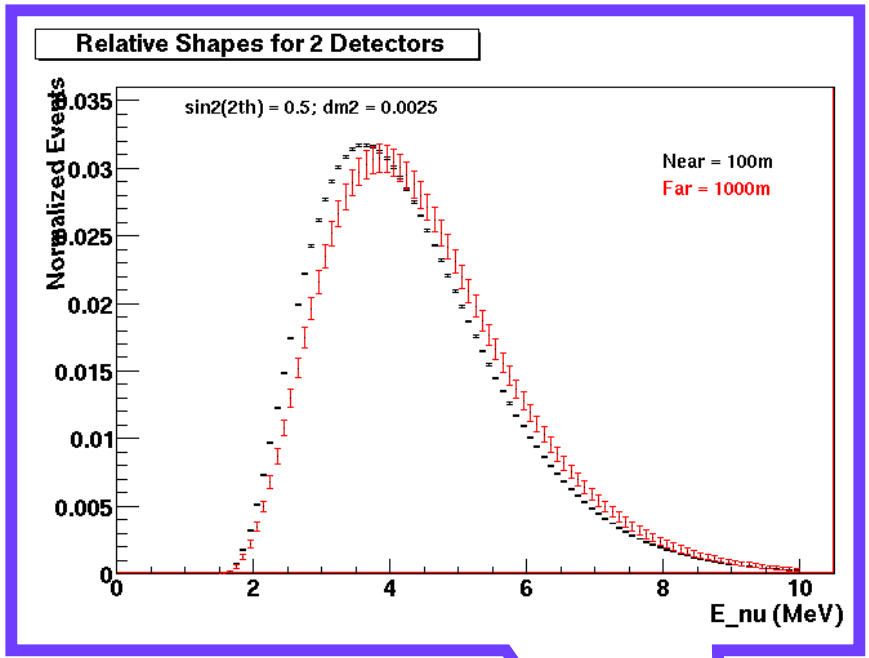


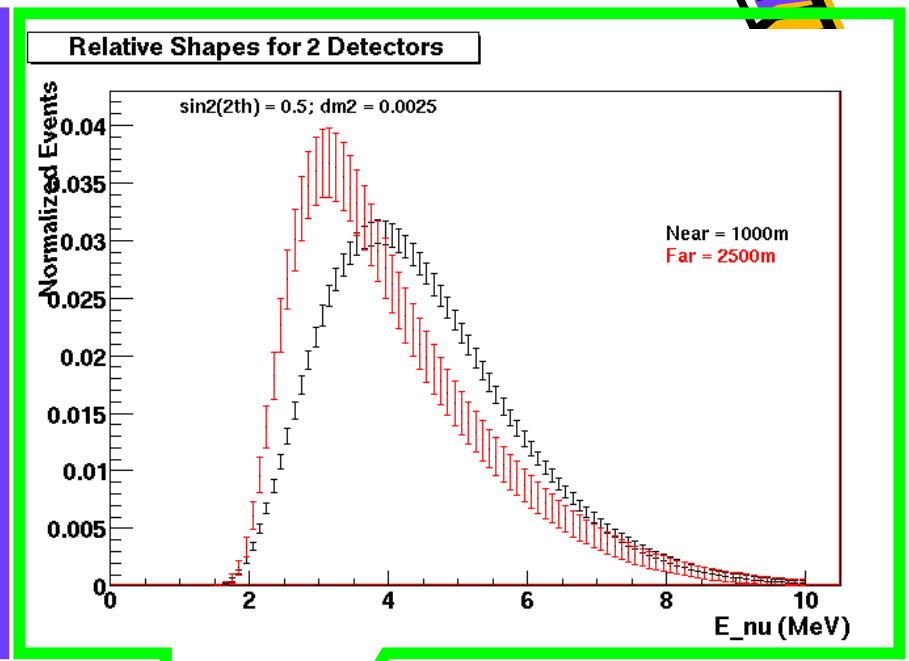
$\Delta m^2 = 0.0015$
0.002
0.0025
0.003
0.0035

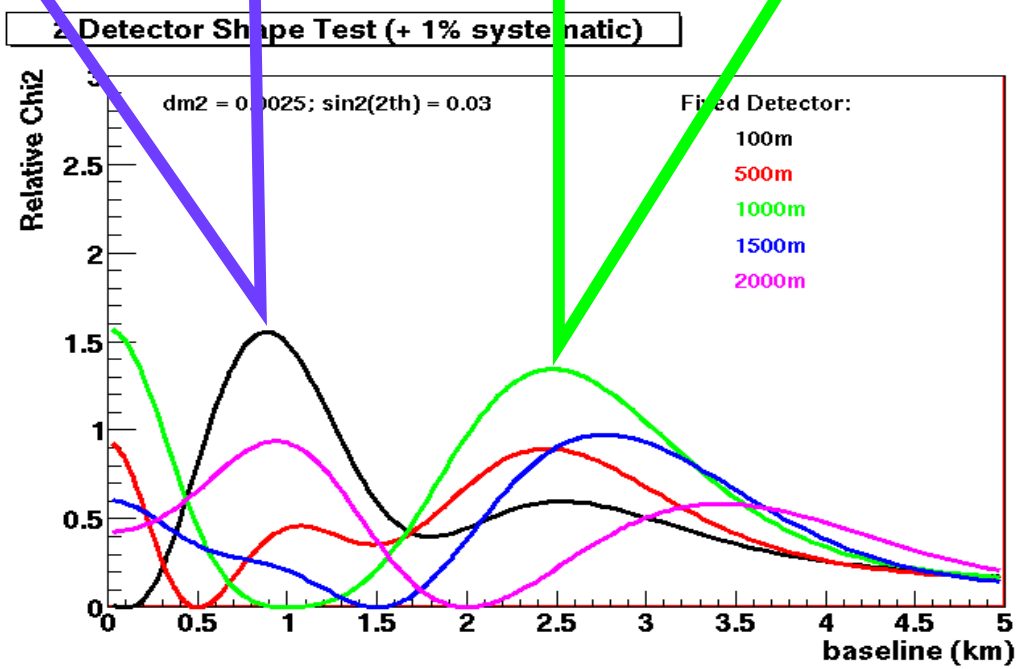
90% Confidence Limits



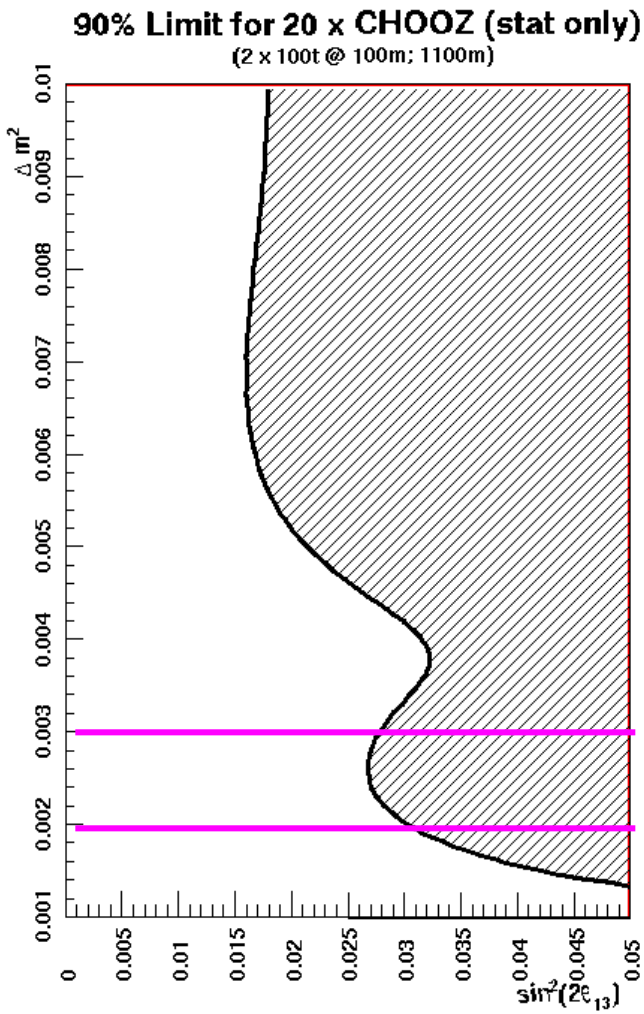


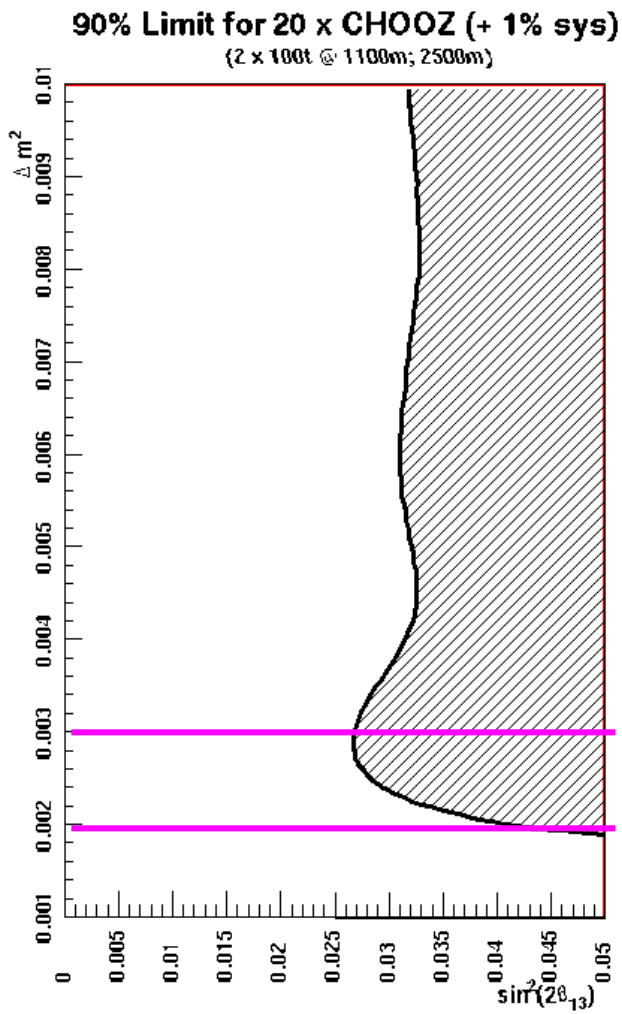

Relative Shapes for 2 Detectors
sin2(2th) = 0.5; dm2 = 0.0025
Near = 100m
Far = 1000m
Normalized Events
E_nu (MeV)


Relative Shapes for 2 Detectors
sin2(2th) = 0.5; dm2 = 0.0025
Near = 1000m
Far = 2500m
Normalized Events
E_nu (MeV)

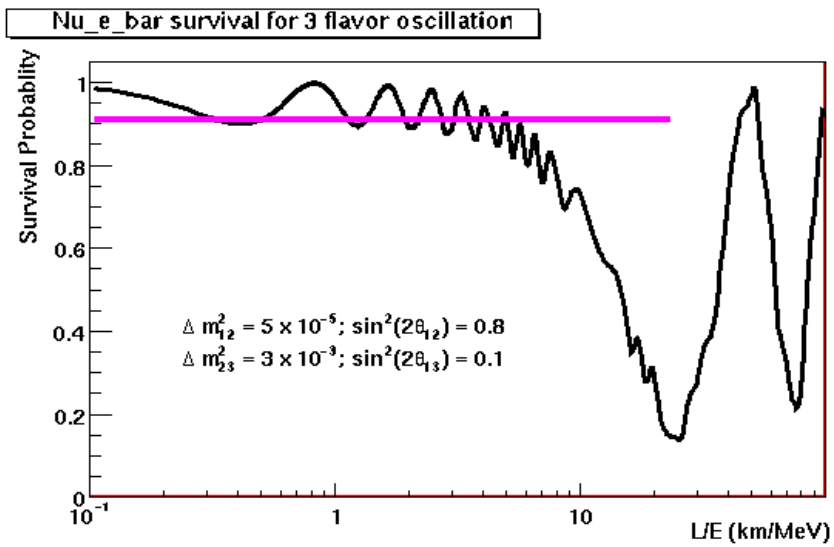

2 Detector Shape Test (+ 1% systematic)
dm2 = 0.0025; sin2(2th) = 0.03
Fixed Detector:
100m
500m
1000m
1500m
2000m
Relative Chi2
baseline (km)

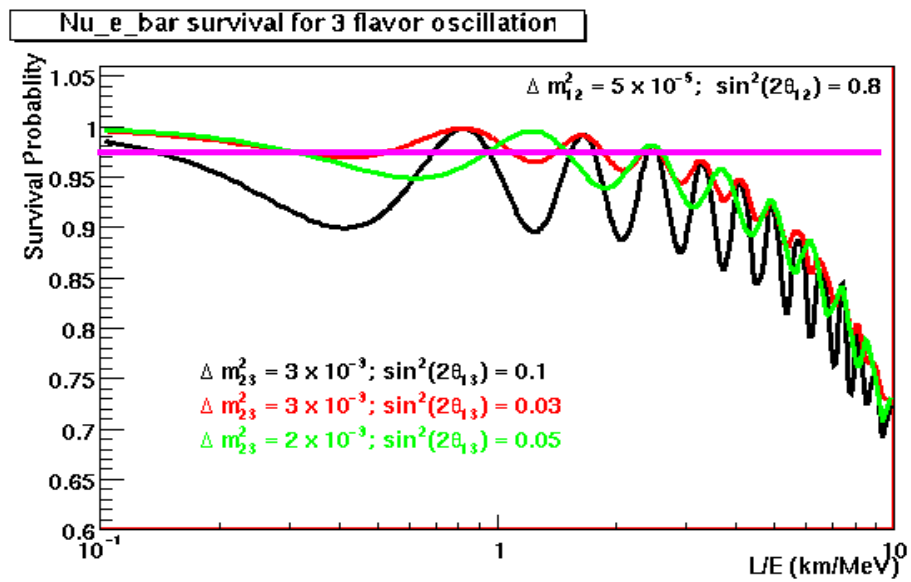
Short and Long Solutions (100t detectors)





Can We Go Too Far?





$$P(\bar{\nu}_e \rightarrow \bar{\nu}_e) = 1 - \cos^4(\theta_{13})\sin^2(2\theta_{12})\sin^2(\Delta m_{12}^2\, L/4E)$$
$$- \sin^2(2\theta_{13})\sin^2(\Delta m_{23}^2\, L/4E)$$

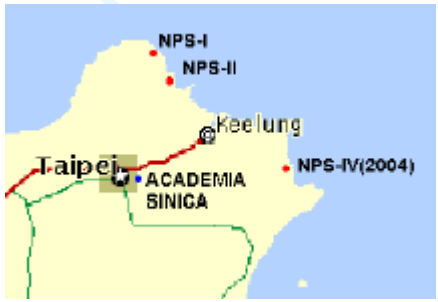
Possible Sites?

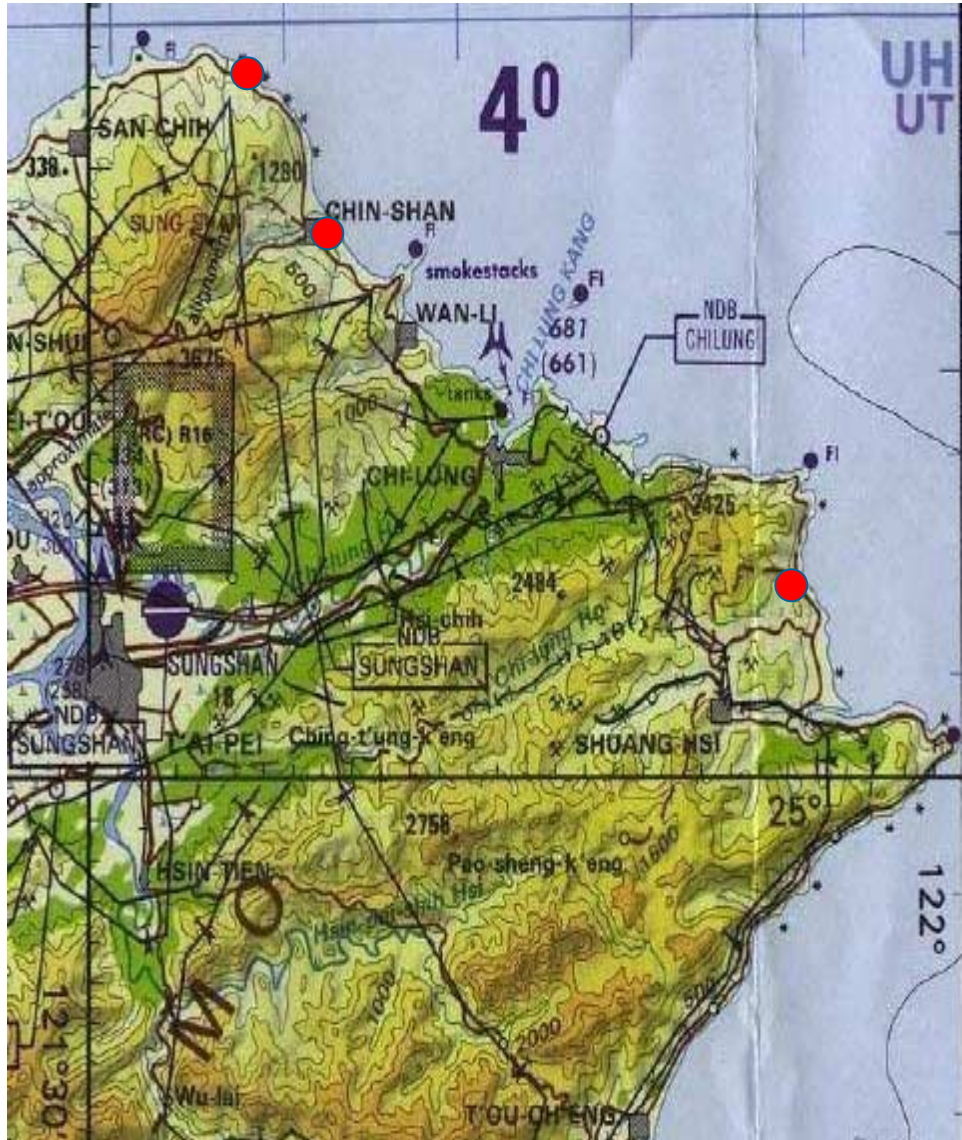
Previous Reactor Experiments and new sites under consideration

Chooz	France	1100 m	8.5 Gw	300 MWE	5 ton
Bugey	France	40/95 m	5.6 Gw	16 MWE	1/0.5 ton
Palo Verde	US	890 m	11.6 Gw	32 MWE	11.3 ton
KamLAND	Japan	180 km	200 GW(26)	2700 MWE	1000 ton
Krasnoyarsk	Russia	115/1000 m	~1 GW	600 MWE	46t
Chooz-2	France	450/1100 m	8.5 GW	?/300 MWE	
Diablo Canon	US (Cal)	(~1 km?)	6.1	600 MWE	
Wolf Creek	US (KS)	(~1 km?)	3.2 GW		
Boulby	UK	25 km	3.1 GW	2860 MWE	
Heilbronn	Germany	19.5 km	6.4 GW	480 MWE	
Kashiwasaki	Japan	1.7 km	24.3 GW		20 ton
Texono	Taiwan	(~2 km?)	4.1 GW(NP4)		
IMB/Perry	US(Ohio)	10 km	1.2 GW	1570 MWE	
Reactor	Location	Detector L	Power	Overburden	Detector M

Texono sites

- Small experiment for ν magnetic moment at NPS-2
- I(1.78 Gw); II(2.90Gw); IV(4.1Gw) now 2006
- Road tunnels and mines in area





Costs (from M. Shaevitz)

Comparison of Possible Scenarios

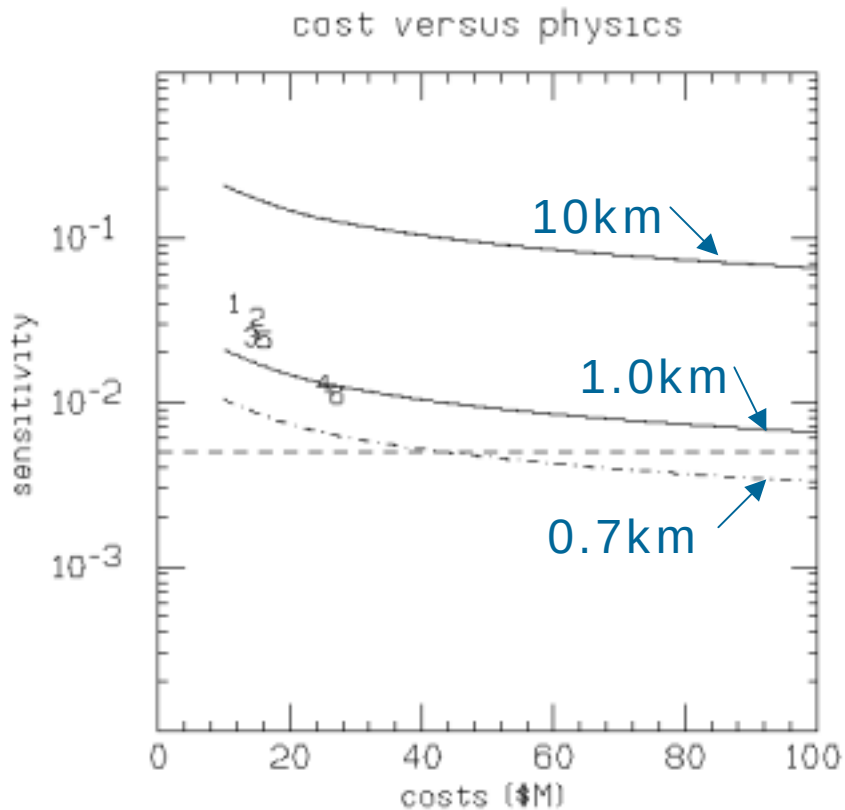
- Example scenarios with 3 year data runs
  - 50 ton far (near) detector at 1200m (150m)
  - One (or two) 3 GW reactors
- Costs
  - Detector based on similar MiniBooNE detector
  - Tunnel/hall cost estimates from NuMI engineer
  - Should add +50% contingency to cost

Unit	Cost ($M)
Detector	5
Hall at 32ft	1
Hall at 300ft	2
Hall at 600ft	3
Tunnel&Halls at 32ft	5
Tunnel& Halls at 300ft	15
Tunnel&Halls at 600ft	17

							$\sin^2 2\theta_{13}$ @ $\Delta m^2 = 2.5\times10^{-3}$	
Source	Depth (mwe)	Detector	Events Far	Background	Rel Norm Err	Cost ($M)	90% CL	3 σ
One Reactor	32	Fixed	64,000	101,000	0.008	12	0.056	0.132
		Moveable	57,000	91,000	0.0023	15	0.052	0.122
	300	Fixed	64,000	10,1000	0.008	14	0.024	0.057
		Moveable	57,000	9100	0.0023	25	0.012	0.029
	600	Fixed	64,000	5100	0.008	16	0.024	0.055
		Moveable	57,000	4600	0.0023	27	0.011	0.027
Two Reactors	32	Fixed	128,000	110,000	0.008	12	0.040	0.093
		Moveable	115,000	99,000	0.0016	15	0.033	0.077
	300	Fixed	128,000	10,900	0.008	14	0.025	0.059
		Moveable	115,000	9900	0.0016	25	0.013	0.031
	600	Fixed	128,000	5500	0.008	16	0.024	0.056
		Moveable	115,000	4900	0.0016	27	0.011	0.025

Physics vs costs

- Scale cost of Chooz ($10M) vs detector size
- 10km, 1.0km, 0.7km
- Stats only
- Comparable to [1-6] Shaevitz estimates
- Looks promising



Conclusions

- First order studies indicate baselines of ~1km and ~2.5km are optimal
- It's conceivable to get the desired sensitivity for ~ $50M
- Need to understand systematic limitations