Update of Reactor Experimental Scenarios

MWReactor
Collaboration Meeting
Jan. 16, 2003

- Update of sensitivity estimates for various proposed reactor experiments
- Comments on reactor / off-axis combined sensitivities

Fitting Program

- Form χ^2 between "observed" and "predicted" event spectrum in energy bins. (100 0.1 MeV bins)

- Systematic uncertainties included through extra fit parameters that are constrained by assumed systematic error:
  - d^{xsec} = 2% xsec error
  - $d_k^{Reactor}$ = 2% reactor k power uncertainty
  - d^{Bkgnd} = 3.5 (14) % background uncertainty
  - d_j^{Near} = 0.23 (0.8) % relative error for near detector j
  - d_j^{Far} = 0.23 (0.8) % relative error for far detector j

$$\chi^2 = \sum_{i,j,k} \frac{(N_{i,j,k}^{ObsFar} - N_{i,j,k}^{Far}(1 - P_{i,j,k}^{OscFar})(1 + d^{xsec}) - N_{i,j}^{FarBkgnd}(1 - d^{Bkgnd}))^2}{N_{i,j,k}^{Far} + N_{i,j}^{FarBkgnd}}$$
$$+ \sum_{i,j,k} \frac{(N_{i,j,k}^{ObsNear} - N_{i,j,k}^{Near}(1 - P_{i,j,k}^{OscNear})(1 + d^{xsec}) - N_{i,j}^{NearBkgnd}(1 - d^{Bkgnd}))^2}{N_{i,j,k}^{Near} + N_{i,j}^{NearBkgnd}}$$
$$+ \left(\frac{d^{xsec}}{\delta_{xsec}}\right)^2 + \left(\frac{d^{Bkgnd}}{\delta_{Bkgnd}}\right)^2 + \sum_j \left(\frac{d_j^{Near}}{\delta_{eff}}\right)^2 + \sum_j \left(\frac{d_j^{Far}}{\delta_{eff}}\right)^2 + \sum_k \left(\frac{d_k^{Reactor}}{\delta_{power}}\right)^2$$

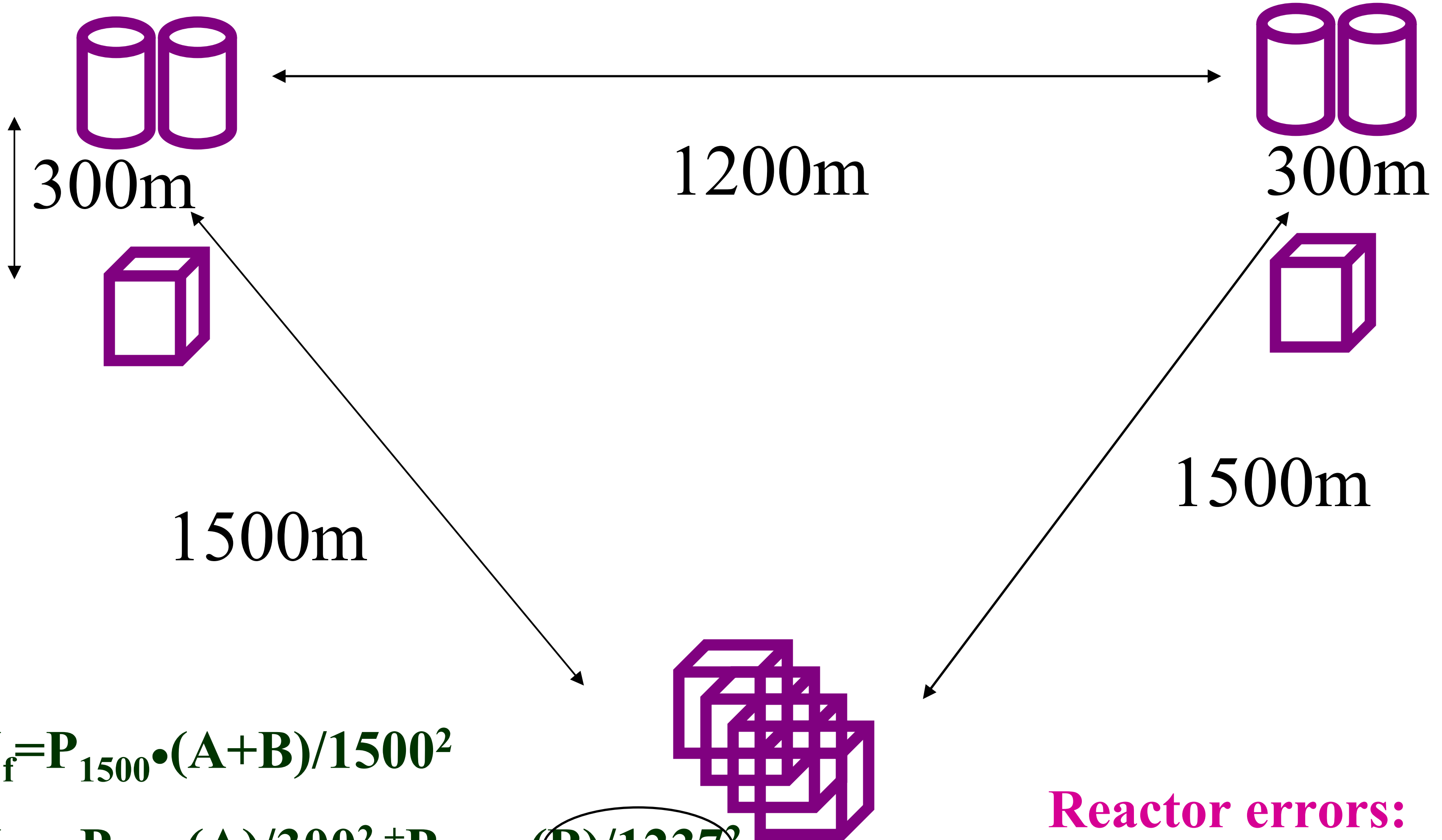
Results for Proposed Sites

Experiment (L_{Far} m)	Detectors	sys_eff (%)	No. of Events Near	Far (each)	Bkgnd	$\sin^2 2\theta$ (90% CL) for Δm^2 (eV^2) 1×10^{-3}	2×10^{-3}	3×10^{-3}
Braidwood (L_{near} = 200 m)								
(1800 m)	3 @ 25 ton	0.23	1.8M	34K	4.5K	0.031	0.013	0.011
(1800 m)	5 @ 25 ton	0.23	1.8M	34K	4.5K	0.025	0.010	0.009
(1800 m)	5 @ 25 ton	0.8	1.8M	34K	4.5K	0.037	0.016	0.015
(1500 m)	5 @ 25 ton	0.23	1.8M	46K	4.5K	0.028	0.010	0.008
Wolf Creek (L_{near} = 250 m)								
(1500 m)	3 @ 25 ton	0.23	660K	25K	4.5K	0.051	0.019	0.014
(1500 m)	5 @ 25 ton	0.23	660K	25K	4.5K	0.041	0.015	0.011
(1500 m)	2 @ 100 ton	0.8	2.64M	100K	18K	0.054	0.022	0.017
Diablo Can.(L_{near} = 400 m)								
(1800 m)	3 @ 25 ton	0.8	507K	30K	4.5K	0.040	0.019	0.017
(1800 m)	5 @ 25 ton	0.8	507K	30K	4.5K	0.036	0.018	0.015
CHOOZ II (L_{near} = 200 m)								
(1050 m)	2 @ 8.5 ton	0.8	750K	34K	352	0.124	0.038	0.025
Kashiwazaki (L_{near} = 325 m)								
(1300 m)	3 @ 8.5 ton	0.8	386K	49K	1.4K	0.056	0.022	0.018
(1500 m)	2 @ 100 ton	0.8	2.64M	100K	18K	0.054	0.022	0.017
Daya Bay(L_{near} = 300 m)								
(1800 m)	6 @ 8.5 ton	0.8	285K	22K	1.5K	0.044	0.021	0.018
(1800 m)	6 @ 8.5 ton	0.23	285K	22K	1.5K	0.032	0.014	0.012
(1800 m)	12 @ 8.5 ton	0.8	285K	22K	1.5K	0.032	0.015	0.013
(1800 m)	12 @ 8.5 ton	0.23	285K	22K	1.5K	0.024	0.010	0.009
Brazil (L_{near} = 325 m)								
(1350 m)	2 @ 50 ton	0.8	1M	68K	9K	0.071	0.025	0.019

Daya Bay Reactor and Surroundings

* Slide from Yifang Wang (IHEP)

Possible Daya Bay Setup



$N_f = P_{1500} \bullet (A+B)/1500^2$

$N_{nA} = P_{300} \bullet (A)/300^2 + P_{1237} \bullet (B)/1237^2$

$N_{nB} = P_{300} \bullet (B)/300^2 + P_{1237} \bullet (A)/1237^2$

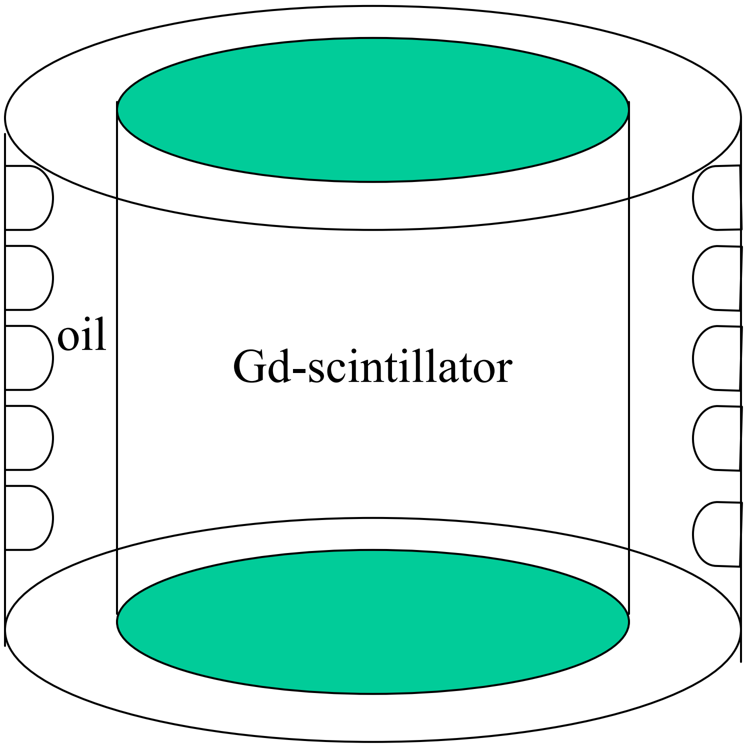
Reactor errors:

~0.1% @ $\Delta A \sim 1.5\%$

Advantages with multiple modules

* Slide from Yifang Wang (IHEP)

- Many modules, 8t each, 100-200 8"PMT/module
- 1-2 at near, 4-8 at far, small enough for movable calibration
- Correlated error cancelled by far/near
- Uncorrelated error can be reduced
- Event rate:
  near: ~500-2000/day/module
  Far: ~40/day/module
- 100 days calibration at the near pit
  → 0.2-0.5% statistical error
- Two reference modules 100 days,
  others ~ 10 days calibration



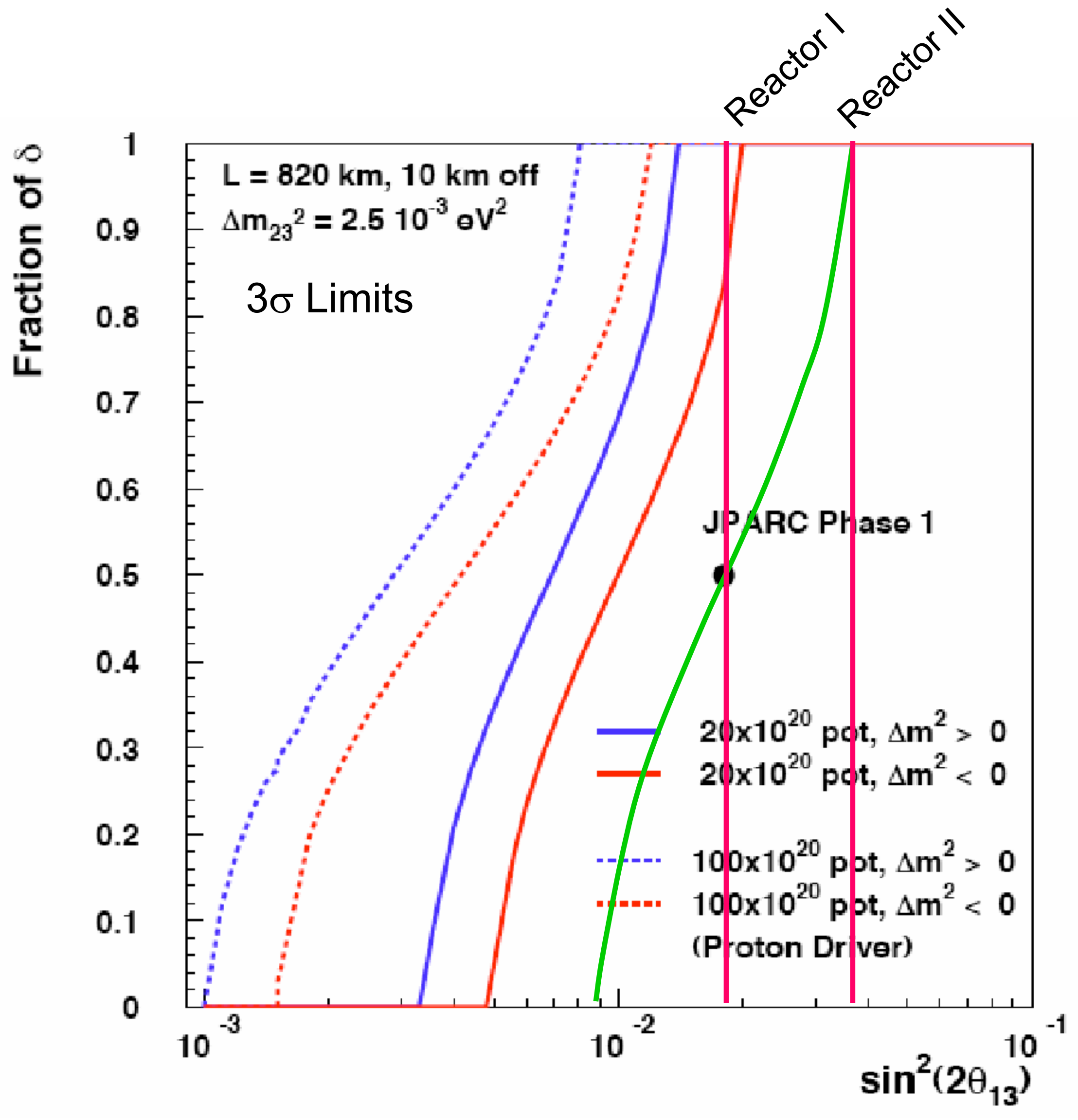
Advantages:

- Smaller modules have less unknowns
- Multiple handling to control systematic error
- Easy construction
- Easy movable detector
- Scalable
- Easy to correct mistakes

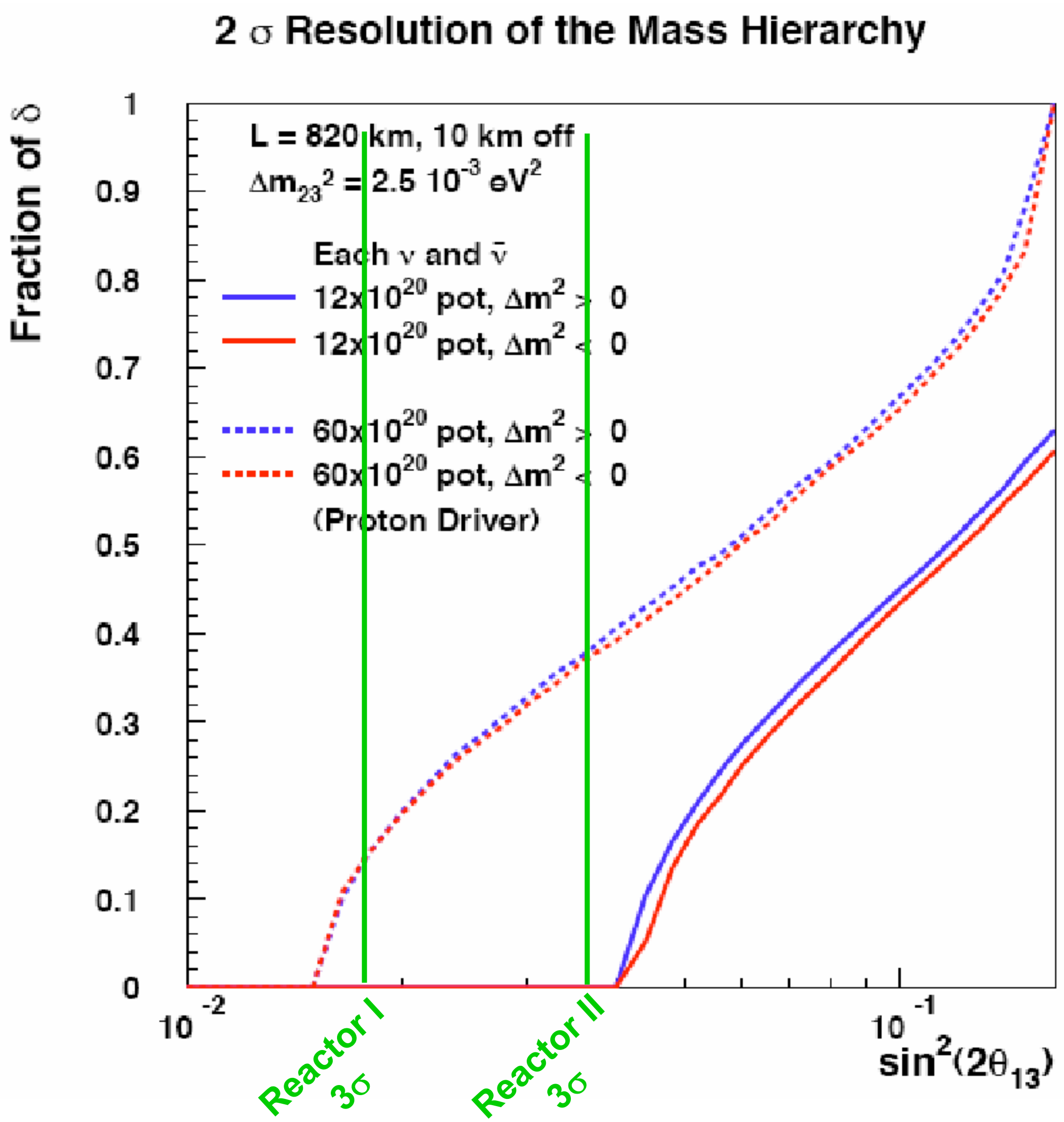
Studies for Comparing and Combining Reactor and Offaxis Measurements

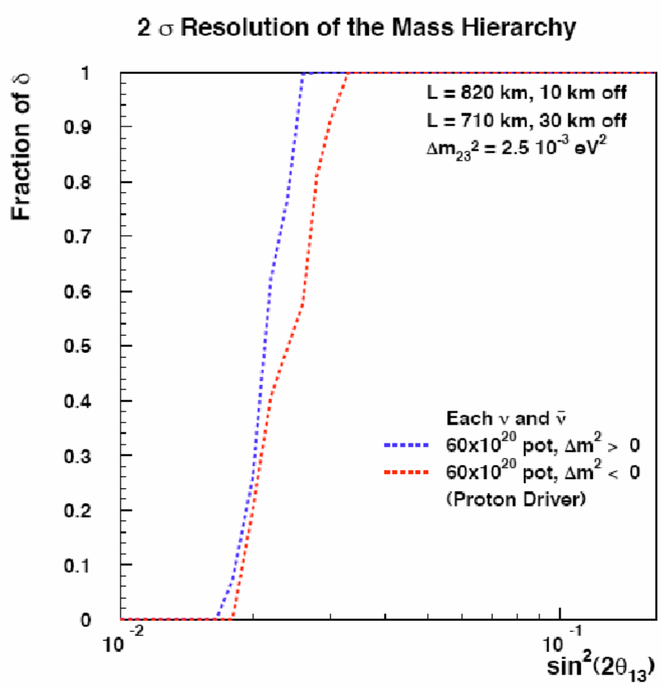
- Work just starting
- Plan: Determine sensitivities to various physics parameters
  - Try combinations of various Offaxis data:
    - JHF Phase I nu , nubar
    - NuMI Phase 1 nu, nubar
    - Reactor measurement with $\delta(\sin^2 2\theta_{13}) = 0.006$ (Reactor I) or 0.012 (Reactor II)
  - Include systematic physics uncertainties
    - $\sin^2 2\theta_{23}$ ambiguity
    - matter effect ambiguity
    - CP violation δ parameter variations
  - Include experimental setups and measurement errors
    - Try to use realistic estimates from the various proposals
    - Include 20% nu contamination in offaxis nubar running
  - Using oscillation code from Stephan Park

Question 1: What is $\sin^2 2\theta_{13}$?



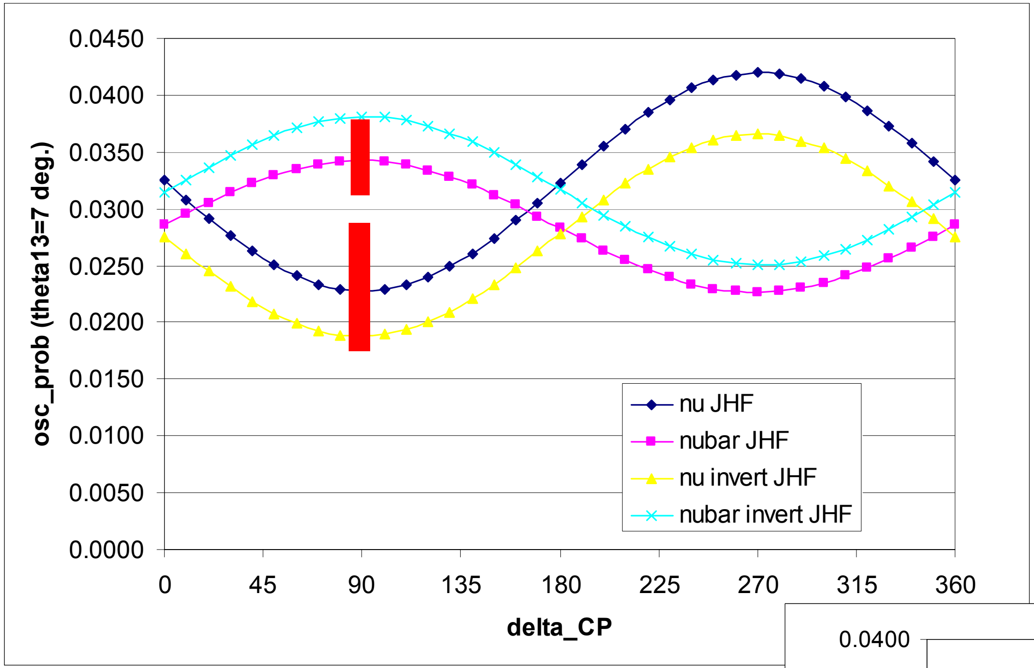
Question 2: What is the mass hierarchy?





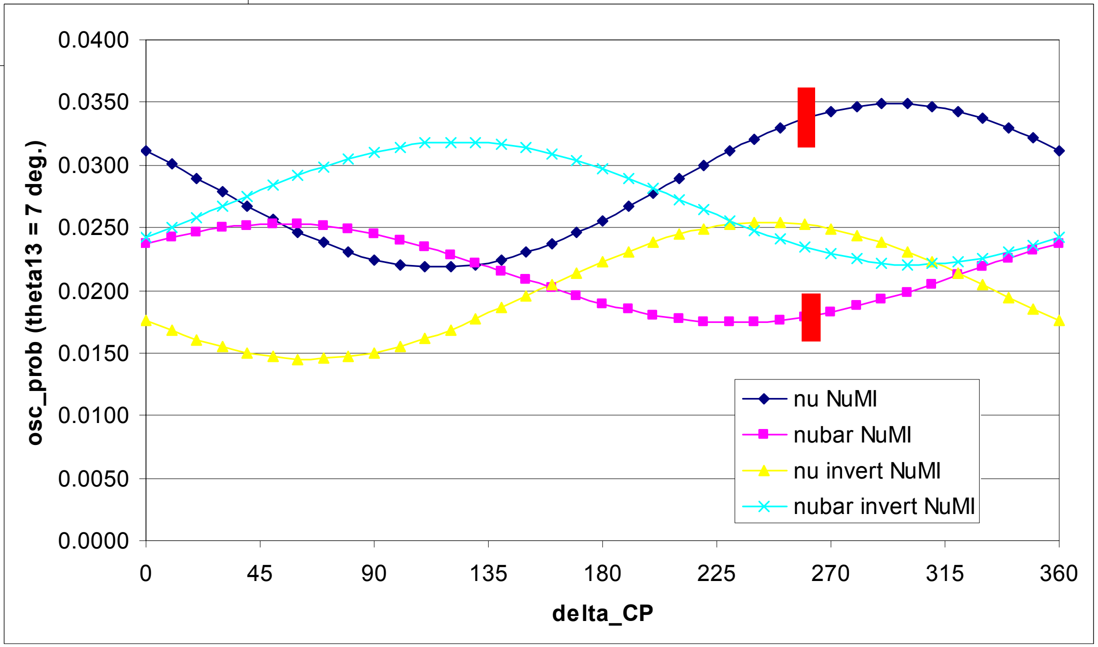
Two! 50kt detectors and Proton Driver can do a better

Question 3: Is there CP Violation? ⇒ Measure δ



JHF
- No matter effects
- Clear CP variation

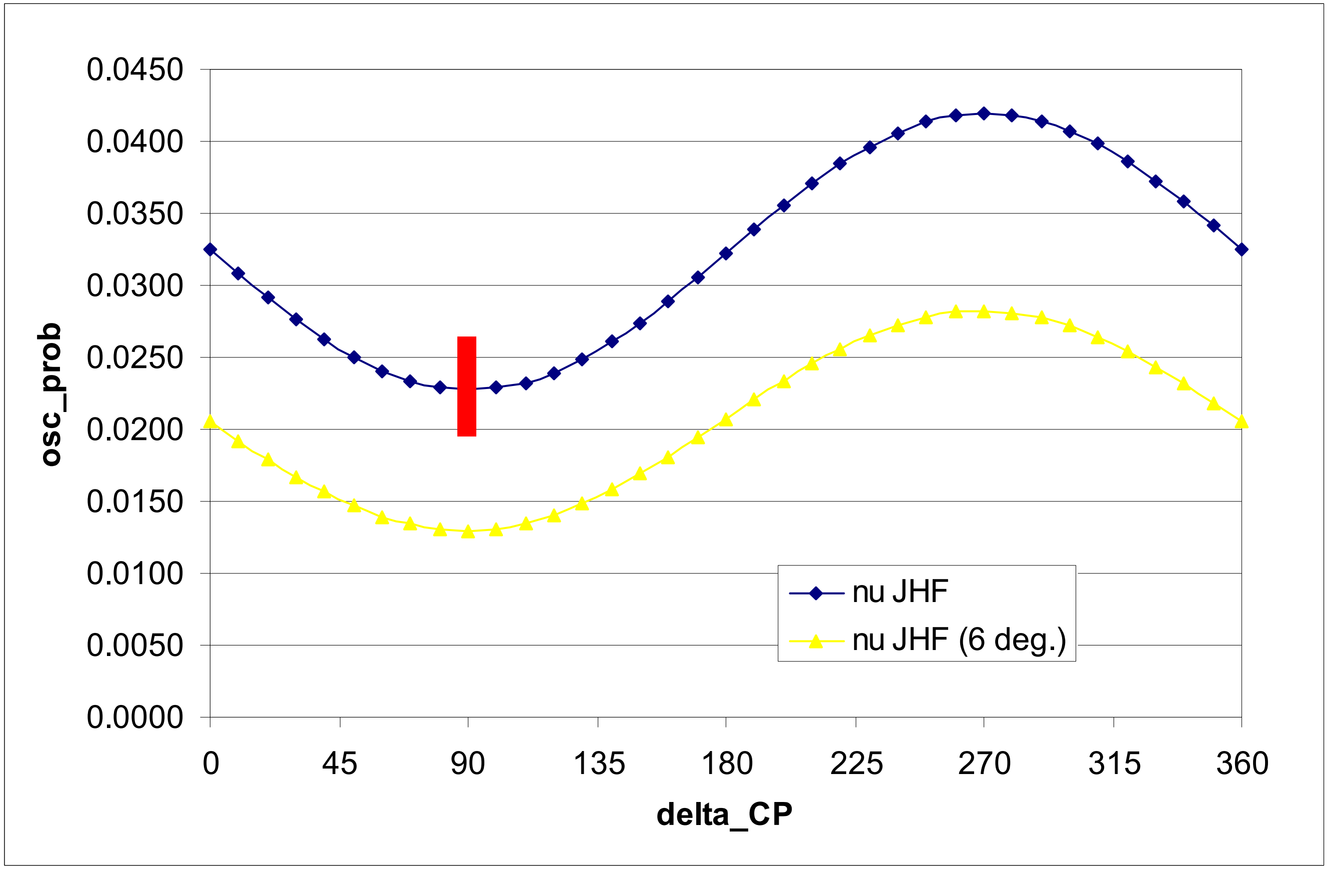
$\theta_{13} = 7°$ or $\sin^2 2\theta_{13} = 0.059$



NuMI
- Large matter effects
- Hard to disentangle matter and CP

Combining Reactor and Offaxis

- Combine JHF nu-only with Reactor ($\theta_{13} = 7.0° \pm 0.5°$)



$\theta_{13} = 7.0° \pm 0.4°$ or $\sin^2 2\theta_{13} = 0.059$

Plans for Further Studies

- Almost setup to do combined fits with reactor, JHF, NuMI offaxis results
- Scenarios: Compare with/without reactor measurement
  - Reactor + JHF (or NuMI offaxis) nu only
  - Reactor + JHF nu only + NuMI offaxis nu only
  - Reactor + JHF (or NuMI offaxis) nu + nubar
  - Reactor + JHF (nu + nubar) + NuMI offaxis (nu + nubar)
- Need to investigate the $\sin^2 2\theta_{23}$ ambiguity
  - Claim is that reactor data really helps here especially if $\sin^2 2\theta_{23} \neq 1$