Physics with a detector at Homestake

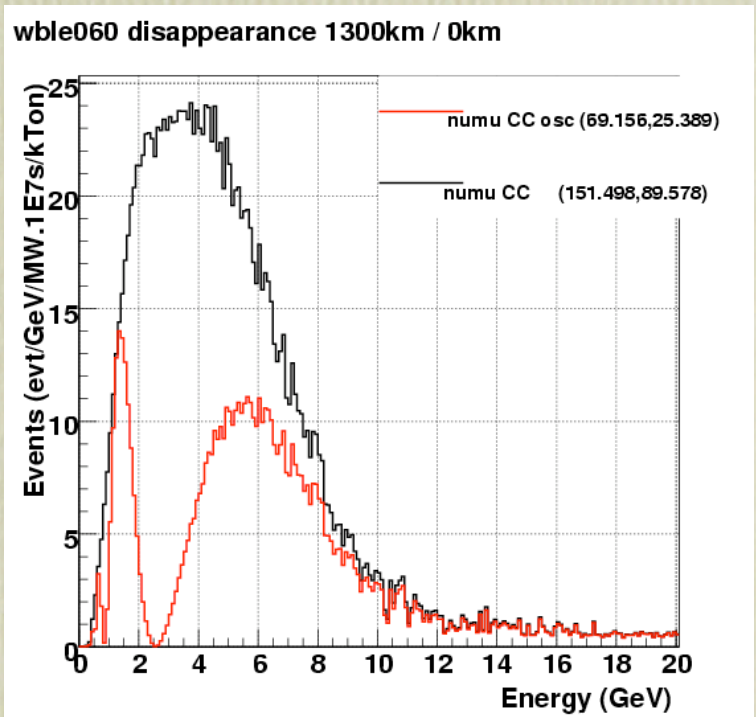
Milind Diwan (BNL)

2/21/2008

SLAC P5 meeting

Total event rate with 300 kT
and
2 MW is
~200000 cc evts/yr ★
(no oscillations, raw events)

The Study: http://nwg.phy.bnl.gov/fnal-bnl



★ yr~2x10^7 sec

- **Proposal for an Experimental Program in Neutrino Physics and Proton Decay in the Homestake Laboratory**

Developing Collaboration

This is the author list of hep-ex/0608023 August 2006

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Outline

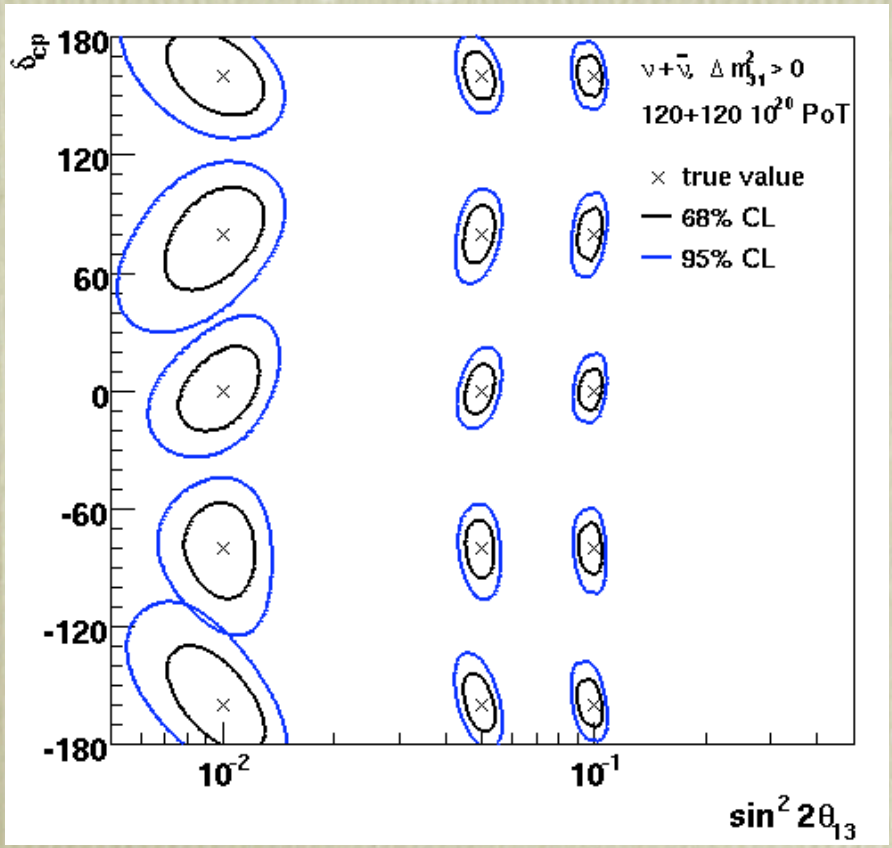
- Scientific/Technical issues for a new long baseline experiment regarding CP violation.
- Ultimate reach with a detector at DUSEL and a conventional beam from FNAL.
- Implementation with the first 100 kT detector.

Scientific strategy

- The Study: A very large detector is needed for the next steps for θ13, mass ordering, and CP violation coming from the standard 3-generation scenario.
- The Study: Program should have broad physics capability: nucleon decay, supernova detection, astrophysical neutrinos.
- Conventional wisdom: Experimental set up with a large matter effect, such as for 1300 km, is more sensitive to possible new physics.
- For neutrino mixing the experiment must have internal redundancy to check 3-gen CP violation and get hints of new physics if they are there.

Technical issues

- Program should lead to measurement of 3-generation parameters without ambiguities. (recall: CP measurement is approximately independent of θ13). Need large detector independent of θ13 value.
- An offaxis program cannot overcome ambiguities easily.



300 kT water Cherenkov detector @DUSEL
Measurement of CP phase and $\mathrm{Sin}^2 2\theta_{13}$ at several points. All ambiguities and mass hierarchy are resolved.

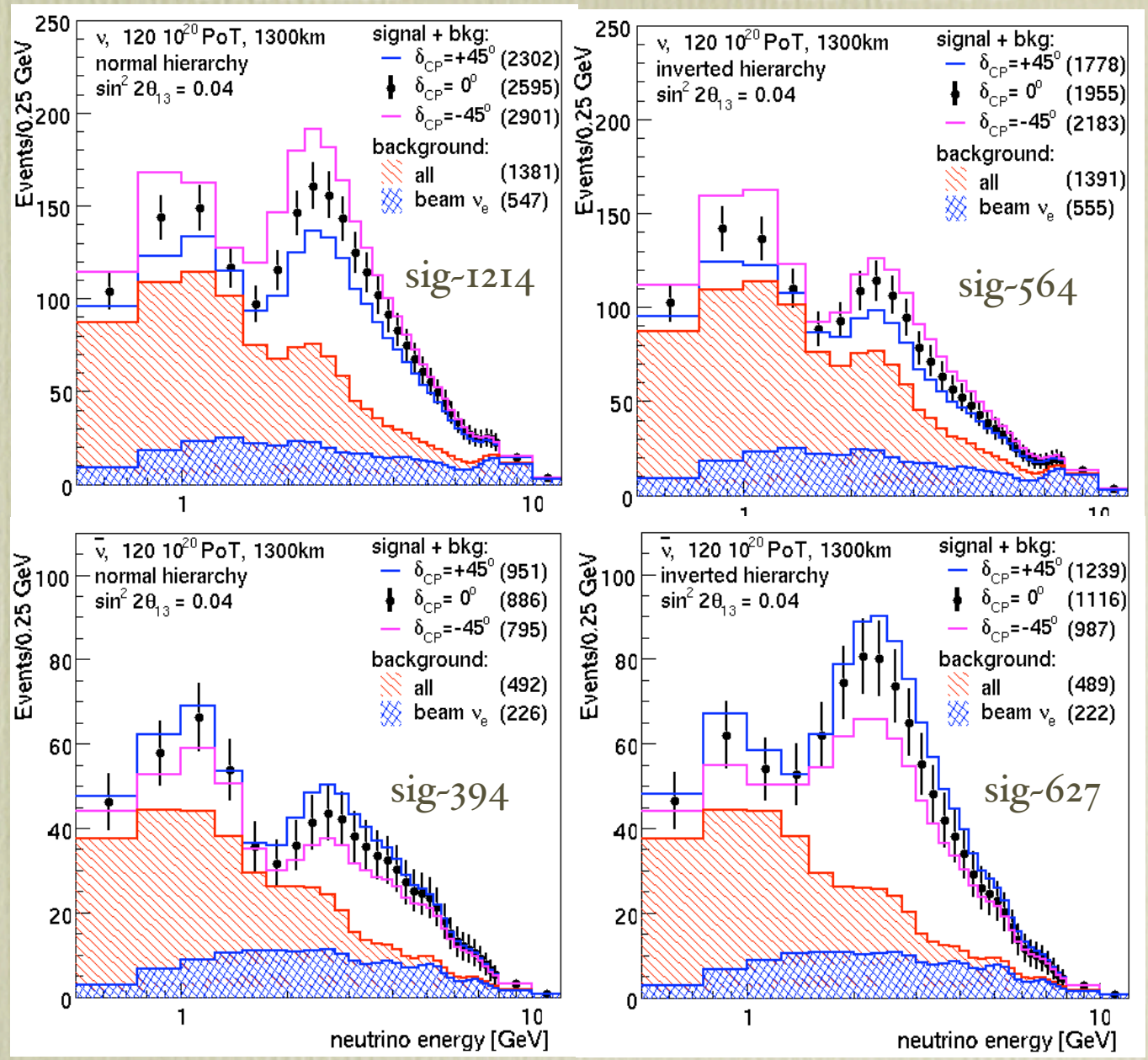
$\sin^2 2\theta_{13}$= 0.04, 300kT, 1300 km, ~2MW @ 60 GeV 3yrs neutrinos and 3yrs antineutrinos

$(-\delta_{cp} = -45°, -\delta_{cp} = +45°)$

Normal Reversed

Spectra with 300 kT detector and 2MW beam from FNAL

- Background issues examined by FNAL/BNL study.



Mark Dierckxsens(UChicago), Mary Bishai(BNL)

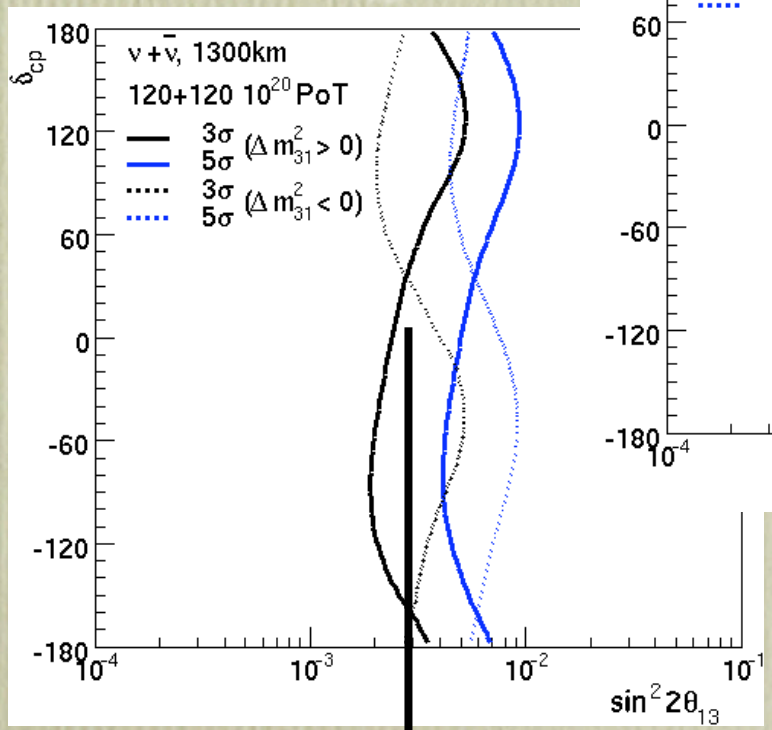
Ultimate Reach

CP Violation

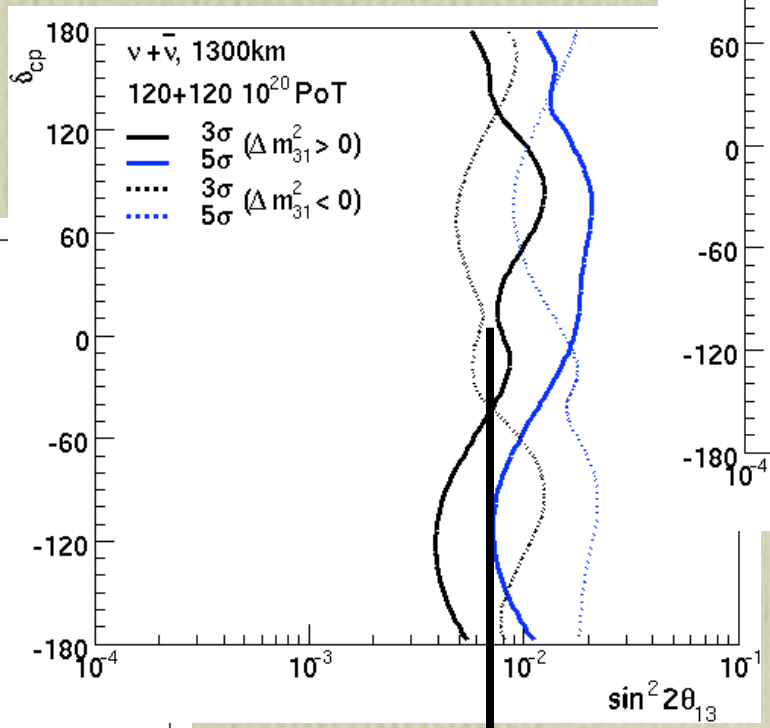
60 GeV, 2MW, 3+3 yrs, 300kT

Mass ordering

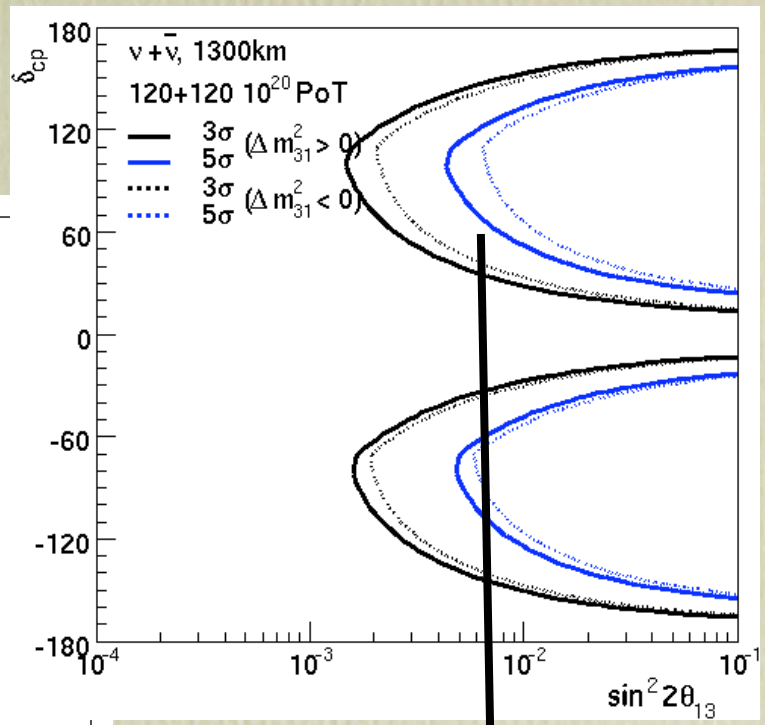
θ_{13}



0.003



0.007



0.007

50% coverage at 3 sigma

stat+ 5%syst

Mark Dierckxsens(UChicago), Mary Bishai(BNL)

Intermediate proposal

- ~100 kT fiducial detector at Homestake with rock mechanics studies starting in fall of 2008. (Homestake Interim Lab. now exists, SuperK and SNO experience and success gives confidence in feasibility and performance.)
- New wide band beam from FNAL (pre-Project x)
- Focus on θ_{13}, and mass hierarchy.
- Get started on CP violation, p-decay, Supernovae.

$\sin^2 2\theta_{13}$= 0.04, 100kT, 1300 km, ~1 MW 60GeV 3yrs neutrinos and 3yrs antineutrinos

$(-\delta_{cp} = -45°, -\delta_{cp} = +45°)$

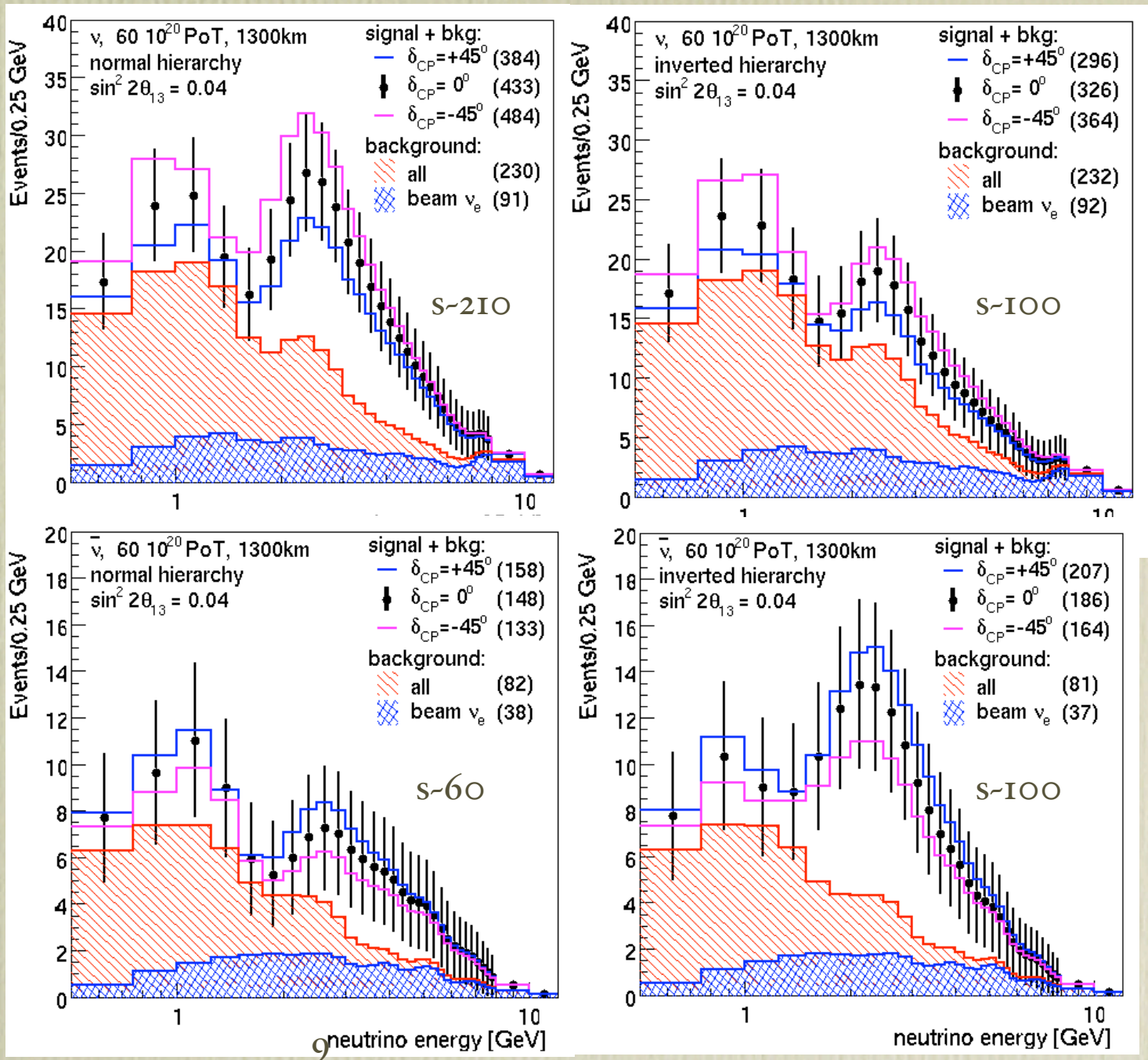
Normal

Reversed

Spectra with 100 kT detector and 1 MW beam from FNAL

Total rate of events ~30k/yr

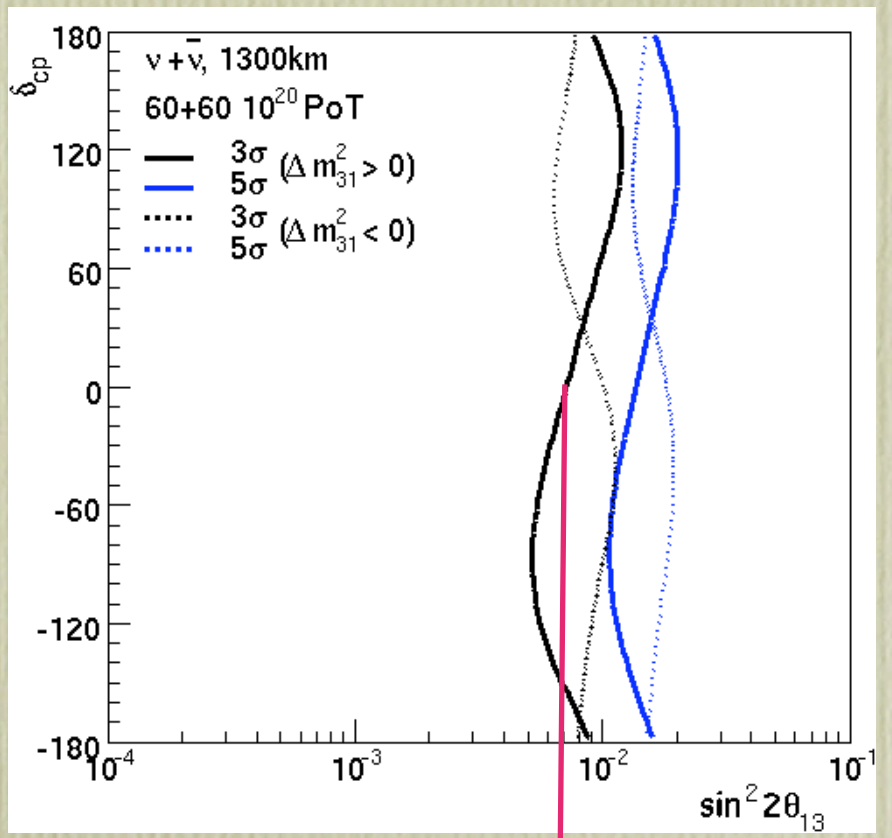
noosc/raw evts



Reach with 100 kT water Cherenkov

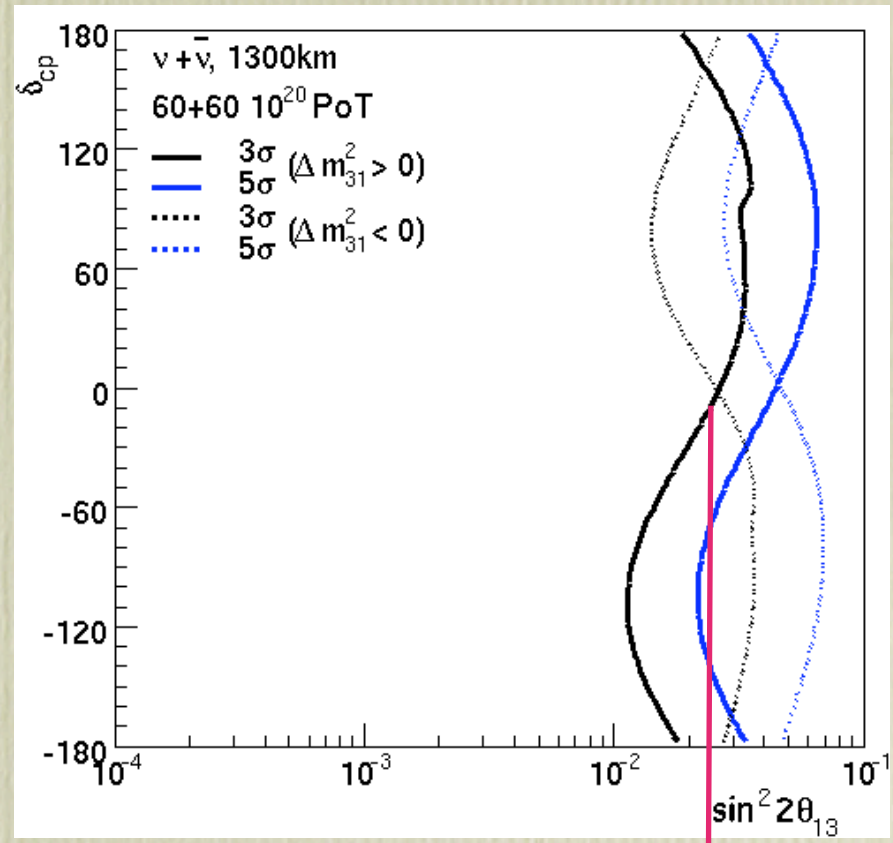
60 GeV, 1MW, 3+3 yrs, 100kT

θ_{13}



0.008

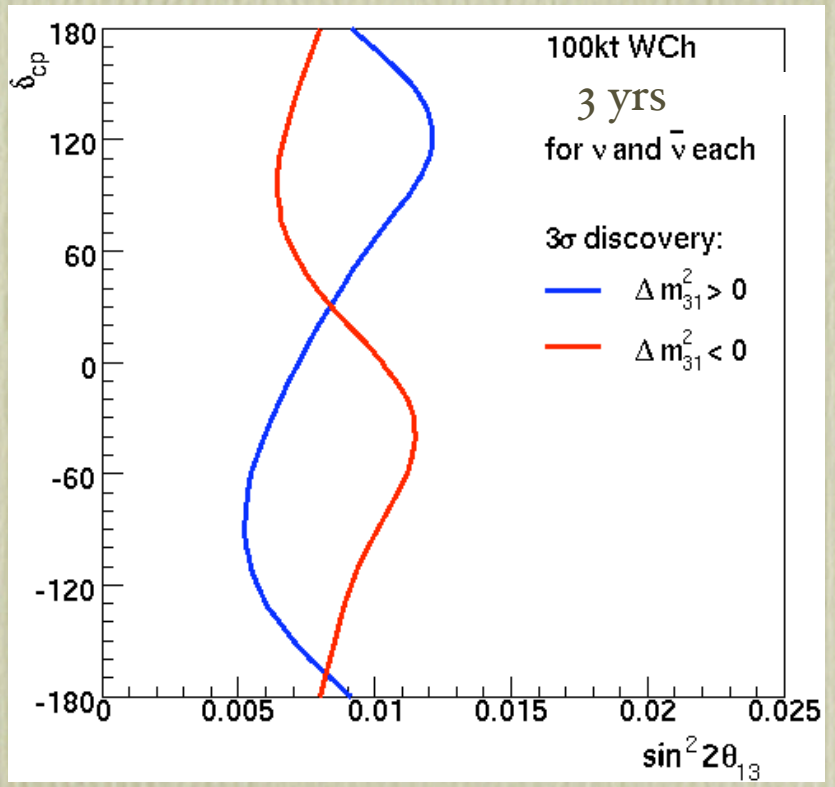
Mass ordering



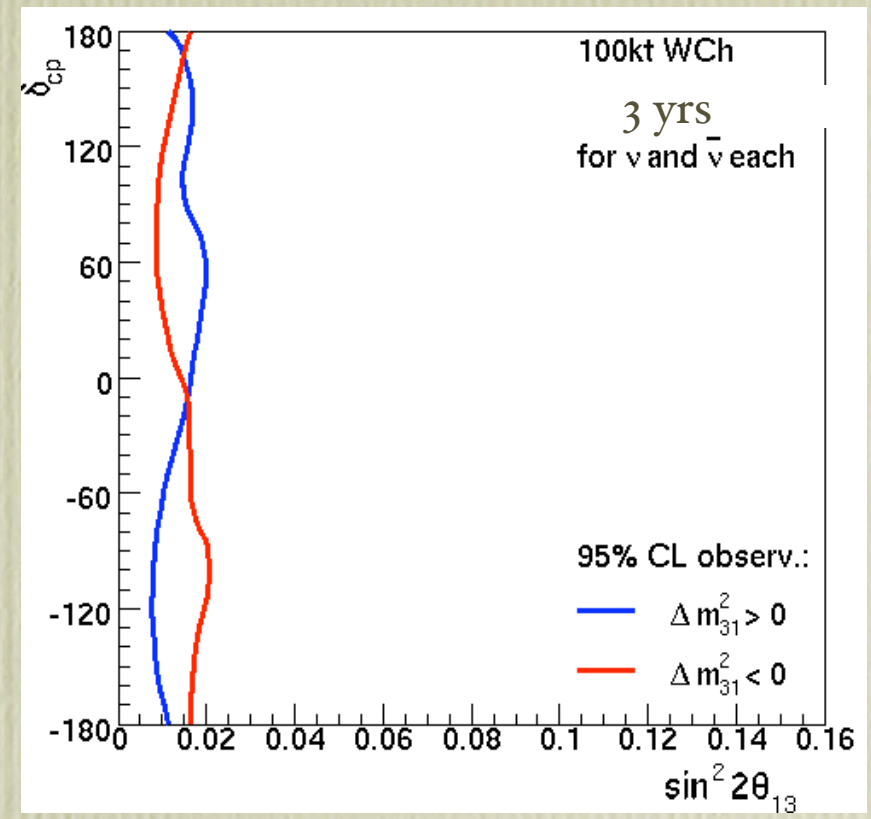
0.025

50% coverage at 3 sigma stat+5% syst

Same plots detail



θ13

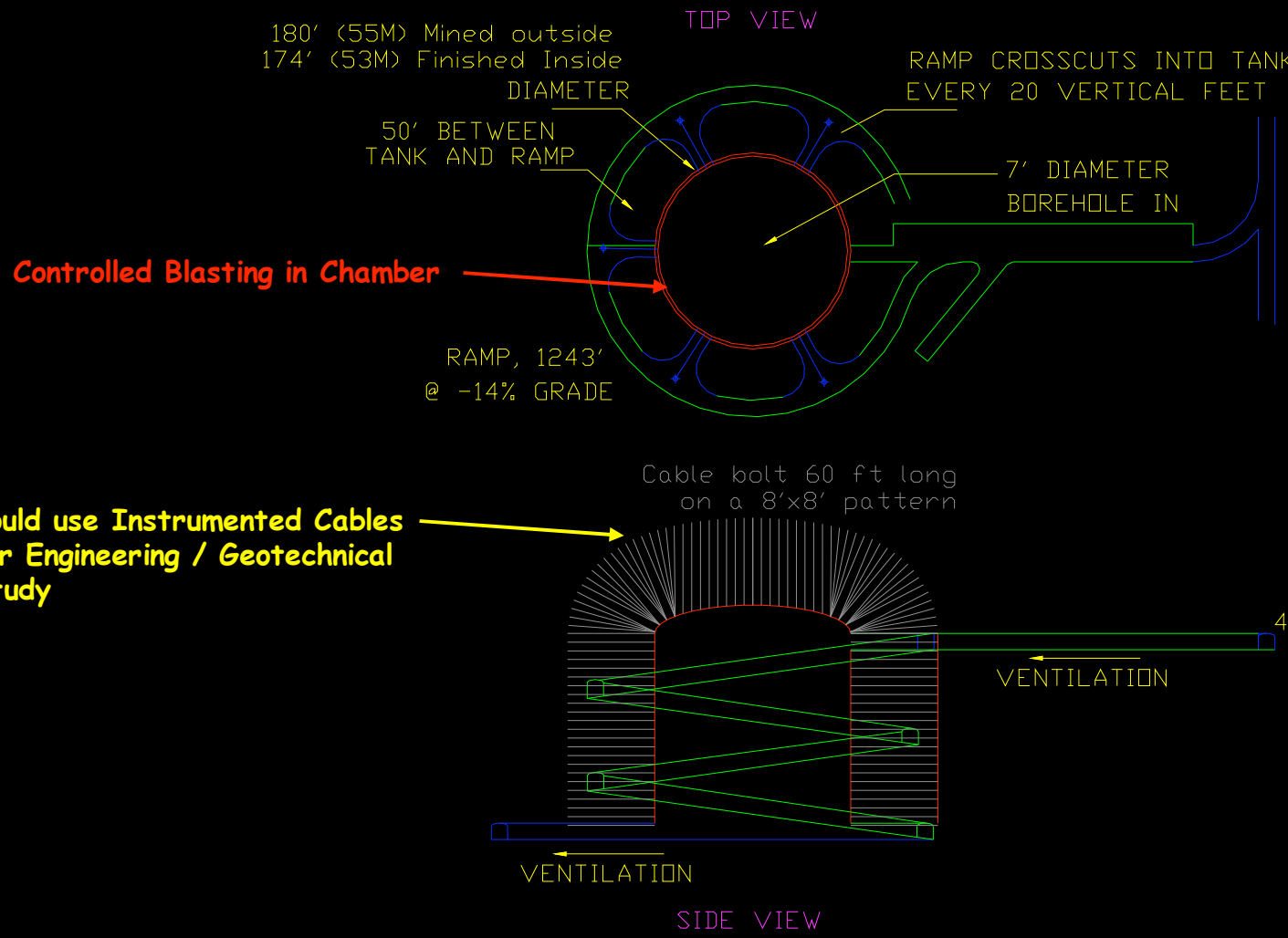


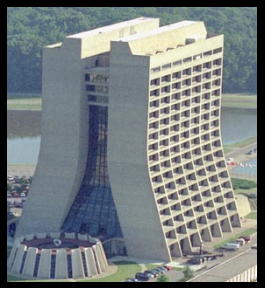
Mass ordering @ 2 sigma

- Same exposure in MW*10^7 sec as previous plot

MEGATON MODULAR MULTI-PURPOSE NEUTRINO DETECTOR

✓ Chamber Design

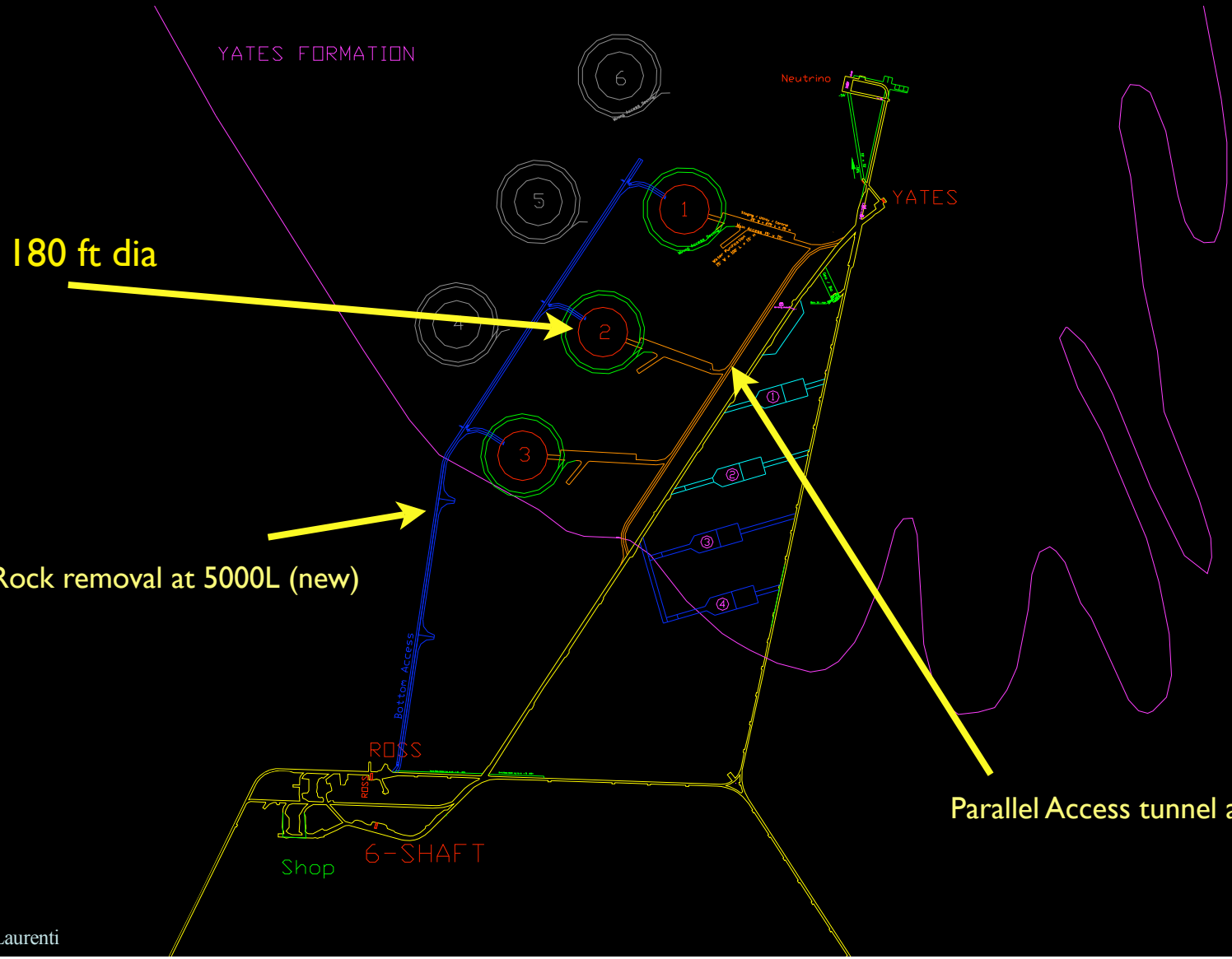




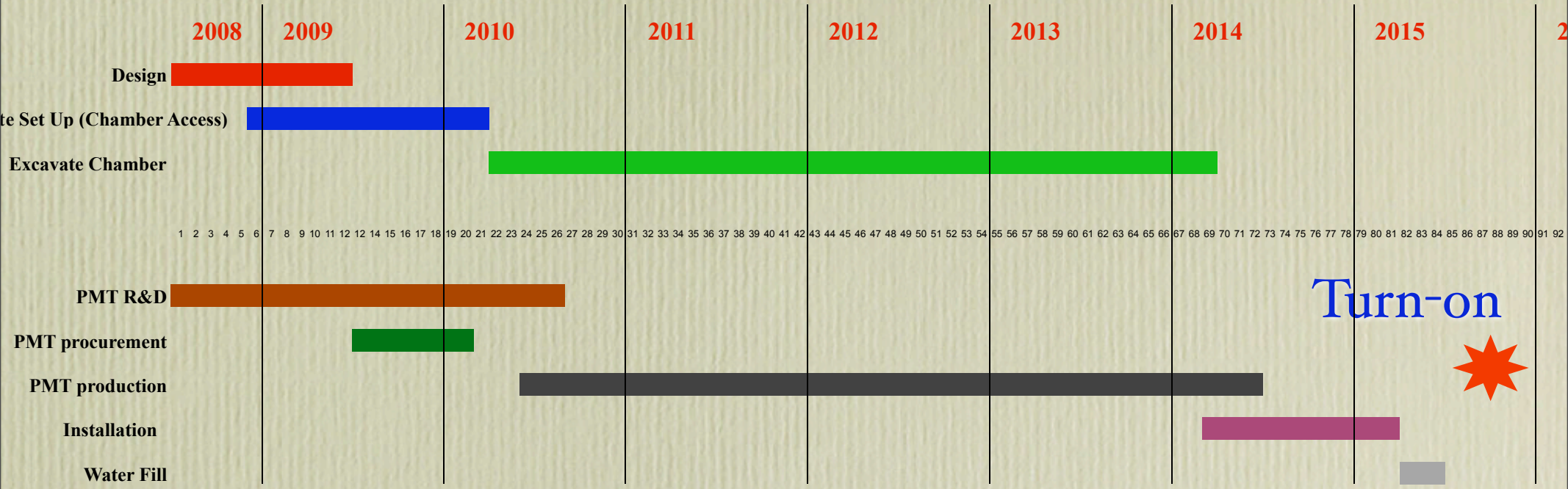
Megaton Modular Multi-Purpose Neutrino Detector

✓ **Modular Configuration**

muon rate/cavern~1/10 Hz



Technically limited schedule for a single 100 kT fiducial detector



Comments: Phototube production is slowed down to match construction of 1 module only.
Schedule is strictly technical. Does not account for review process. See KTLesko talk
PMT testing facility, water system procurement and installation, and other items are not shown here.

- Tube production is slowed to match excavation. Tube production is NOT the limiting factor.
- For simplicity, water system, PMT testing, electronics, etc. are not shown.
- For 300 kT the time need not be tripled.

One time costs over next 3 yrs

- 100kT estimate on next page does not include R&D and one time costs that are needed to establish the entire facility for the megaton-class detector.

Item	Cost	Source
Chamber design and coring	$0.76M	Laurenti
Access tunnels	$4.5M	Laurenti
Contingency	$2.6M	50% of above
Mining + other equip.	$10.0M	Laurenti
PMT+Elec. R&D	$4.0M	Prel. Eng.+Subcontracts
Water/materials R&D	$2.0M	Preliminary
Contingency (non-civil)	$3.2M	Equip. has quotes
Total	$27.1M	FY2007

Summary cost for 100kT(do not triple for 300kT)

Item	Cost	Source
Single Cavity construction	$28.1M*	Laurenti
contingency 30%	$8.4M	Preliminary Reviews
PMT(50000 chan)	$46.7M	Auger, NNN05, etc.
Electronics, cables	$10.65M	UPenn+SNO
Installation	$8.75M	Conceptual
Water, DAQ, testing, etc.	$11.4M	Quote, made for 300kT
Contingency(non-civil)	$25.0M	>30% for some items
Total	$139M	FY2007

* Cost and schedule reviewed by RESPEC, does not have rock disposal

Conclusion

- 100kT detector could be ready for physics by mid decade (~2015).
- Unique physics capability in the world. Excellent sensitivity for θ_{13} and mass ordering.
- Get started on much larger program for CP violation, Nucleon decay, and Supernova physics.
- Subsequent caverns could house different technology: better PMTs, Liquid Scintillator, Liquid Argon ...

Summary Of Chamber Excavation

	TOTAL	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
Chamber (1)								
Cost / Chamber	**$ 28,059,334**							
	$ 28,059,334	**$ -**	**$ 6,980,751**	**$ 6,547,486**	**$ 6,815,666**	**$ 6,816,318**	**$ 899,113**	**$ -**
Top Cut (40 ft high)	**84,820 Tons**	-	84,820	-	-	-	-	-
Ramp Top to Bottom	**1,737 ft**	-	1,737	-	-	-	-	-
Bench Tons	**356,310 Tons**	-	-	127,170	101,970	127,170	-	-
Cable Bolt Feet	**275,840 ft**	-	41,760	64,480	69,360	85,240	15,000	-
Shot Crete	**1,800cuYd**	-	1,800	-	-	-	-	-
Concrete Panels	**2,376**	-	-	486	950	670	270	-
Bore Hole Feet	**174 ft**	-	-	174	-	-	-	-
Months	**49**	-	12	12	12	12	1	-
Labor	**$ 12,983,488**	**$ -**	**$ 2,836,460**	**$ 3,290,928**	**$ 3,290,928**	**$ 3,290,928**	**$ 274,244**	**$ -**
Equipment Operating	**$ 6,454,728**	**$ -**	**$ 1,964,088**	**$ 1,601,206**	**$ 1,302,336**	**$ 1,491,840**	**$ 95,256**	**$ -**
Supplies	**$ 8,534,118**	**$ -**	**$ 2,180,203**	**$ 1,568,350**	**$ 2,222,402**	**$ 2,033,550**	**$ 529,613**	**$ -**
Other	**$ 87,000**	**$ -**	**$ -**	**$ 87,000**	**$ -**	**$ -**	**$ -**	**$ -**

From Mark Laurenti

Excavation costs do not include

- General operations: mine, shaft, pumps, ventilation
- Overhead functions: office, property maintenance, water consumption, power.
- Mobilization/demobilization
- Waste handling
- EDIA
- Do not triple for 3 caverns.

Collaboration requesting funds from DUSEL R&D

One time costs

Summary Of Chamber Excavation

	TOTAL	Year 1	Year 2
Design (3 Chambers)			
	$ 761,600	**$ 761,600**	**$ -**
Months	**7**	7	-
Diamond Drilling ft	**10,932 ft**	10,932 ft	0
Diamond Drill Costs	**$ 546,600**	$ 546,600	$ -
Geotechnical Over site	**$ 90,000**	$ 90,000	$ -
Geotechnical Modeling & Recommendations	**$ 125,000**	$ 125,000	$ -
Site Set Up (6 Chamber Access)			
	$ 4,514,164	**$ 3,958,652**	**$ 555,511**
Drift Footage	4,667 ft	4,459 ft	208 ft
Months	**8**	7	1
Labor	**$ 2,153,632**	$ 1,879,388	$ 274,244
Equipment Operating	**$ 1,143,072**	$ 952,560	$ 190,512
Supplies	**$ 1,217,460**	$ 1,126,704	$ 90,755
Other	**$ -**	$ -	$ -

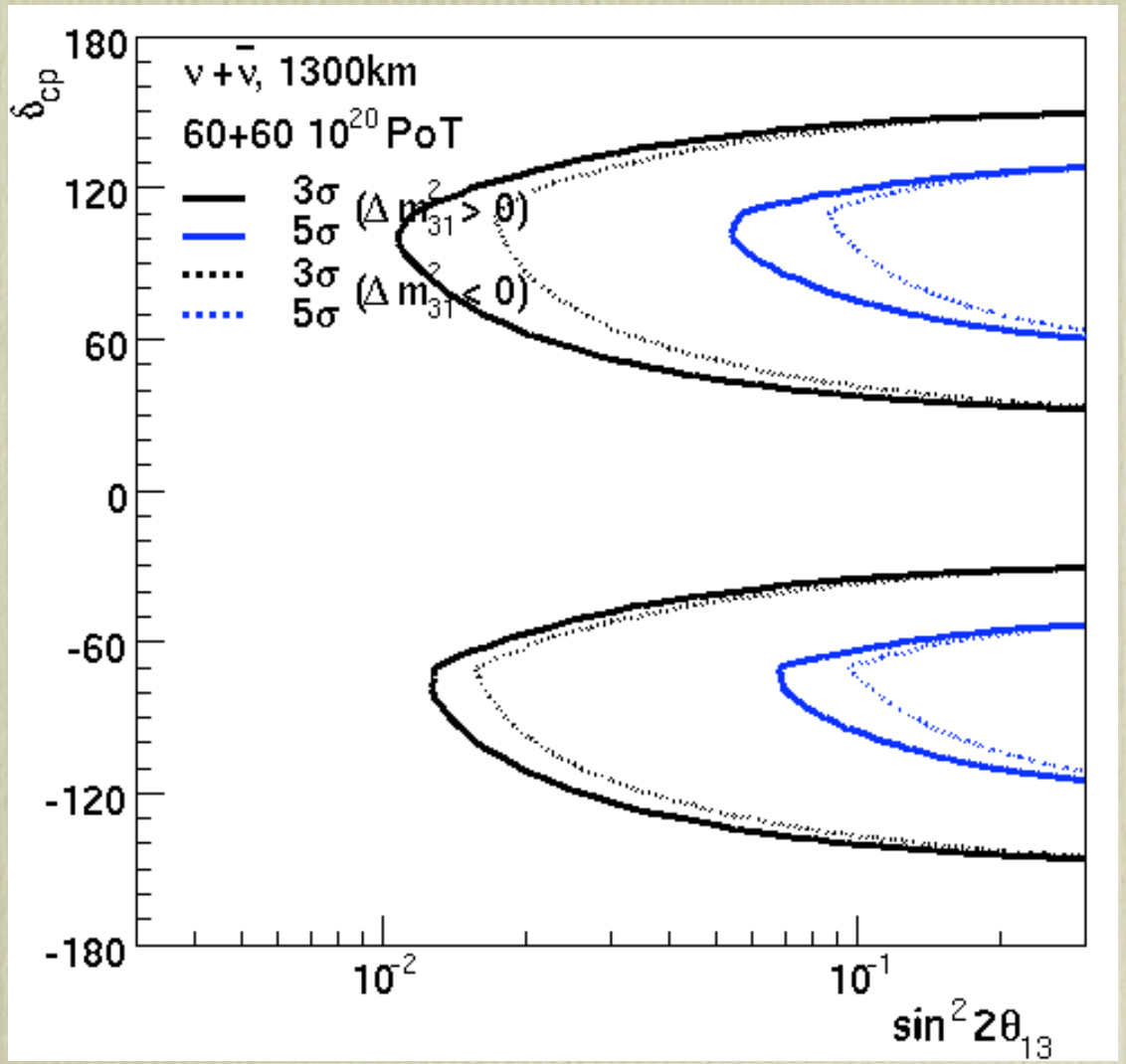
From Mark Laurenti

Capital Investment

TOTAL				**$**	**10,020,000**
MINING EQUIPMNET					
	Units		Price Ea		Total $
			Sub Total	**$**	**9,040,000**
Face Drill (2 Boom)	2	$	860,000	$	1,720,000
Bench Drill	2	$	425,000	$	850,000
Bolter	1	$	800,000	$	800,000
Cable Bolter	1	$	1,245,000	$	1,245,000
Load Haul Dump	4	$	800,000	$	3,200,000
Haul Truck				$	-
Explosive Truck	1	$	300,000	$	300,000
Sissor Lift	2	$	250,000	$	500,000
Utility Lift	1	$	200,000	$	200,000
Transport	3	$	75,000	$	225,000
Jacklegs	6	$	6,000	$	36,000
OTHER EQUIPMENT					
			Sub Total	**$**	**980,000**
Explosive Mag	2	$	100,000	$	200,000
Vent Fan	6	$	30,000	$	180,000
Shop Equipment	1	$	500,000	$	500,000
Fuel Tanks	1	$	100,000	$	100,000

From Mark Laurenti

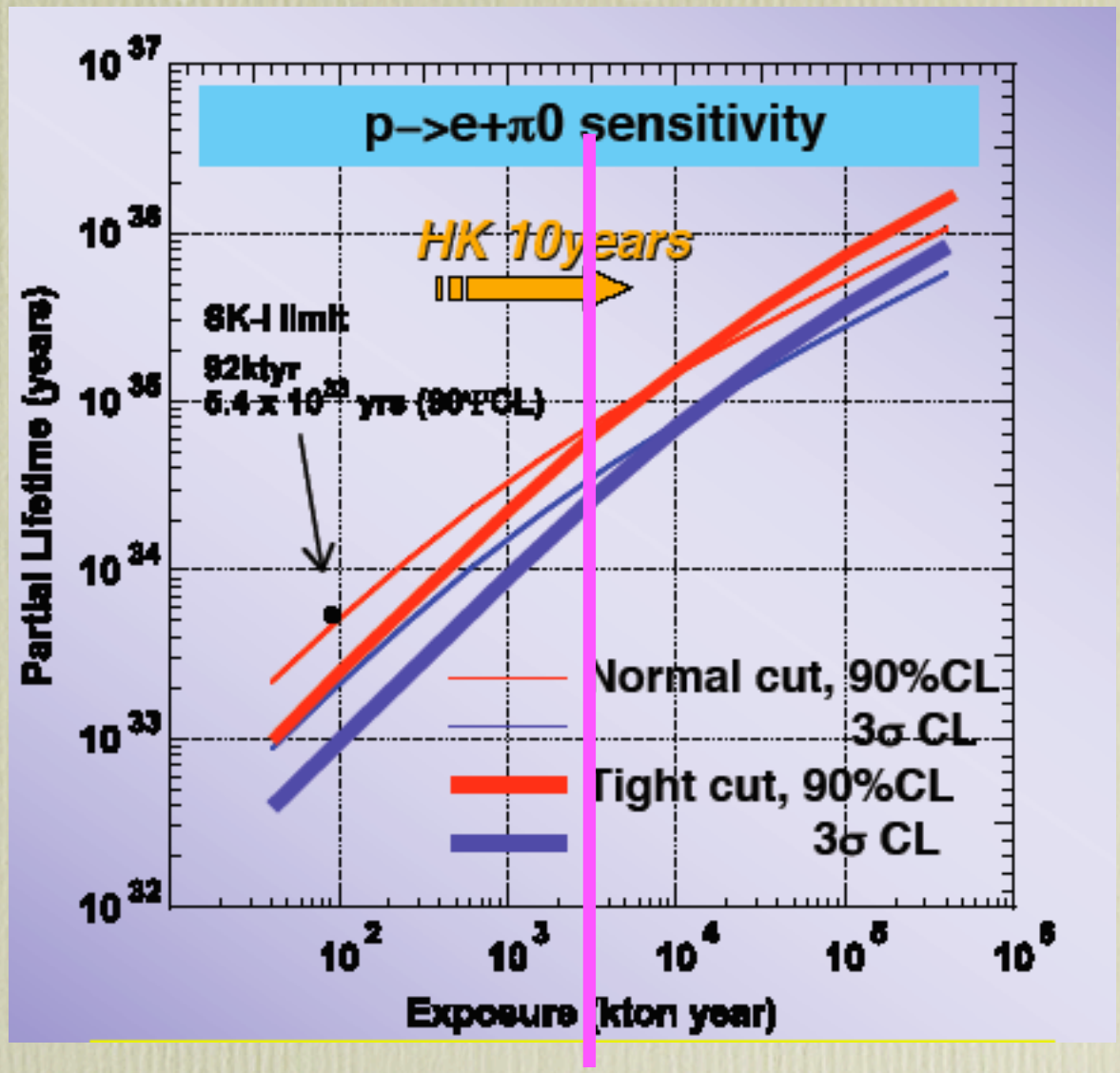
100kT water Cherenkov CP reach



Nucleon decay and Supernova

- Large body of work by HyperK, and UNO.
- background levels for the positron+Pion mode
  - 3.6/MTon-yr (normal)
  - 0.15/MTon-yr (tight)

Sensitivity on K-nu mode is about ~8x10^{33} yr



Ref: Shiozawa (NNN05) 300kTX10yrs => 7X10^{34} yrs

Galactic Supernova in 300kT: 100000 evts/10sec