

# NOvA With More Exposure

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Intensity Frontier Workshop

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Beam power	POT/yr	Detector mass	Exposure [10 <sup>20</sup> POT-kt]		Equivalent exposure years of baseline exposure
			1 year	6 years	
[kW]	x10 <sup>20</sup>	[kt]			
<b>700</b>	<b>6.0</b>	<b>14</b>	<b>84</b>	<b>504</b>	<b>6</b>
2300	19.7	14	276	1656	19.7
2300	19.7	28	552	3312	39.4

- The purpose of these slides are to explore the limits of the “current” facilities (NuMI@700 kW + NOvA) as a baseline for future projects
- The NOvA **baseline** exposure is NuMI at 700 kW (6E20 protons on target/yr) with a 14 kt detector
- In the spirit of this workshop, let’s imagine 2 scenarios **beyond the baseline**:
  - ▶ NOvA runs with 14 kt in a Project-X-fed neutrino beam (2.3MW delivering 20E20 POT/yr)
  - ▶ In addition to the upgraded beam power, the detector mass is increased to an equivalent of 28 kt (x2). Imagine whatever technology you like, eg. 5 kt LqAr ≈ 14 kt NOvA.
- In all scenarios, I assume a 5% uncertainty in the backgrounds with a 5% “spectrum tilt” uncertainty. Fits are made using GLOBES.
- The “equivalent exposure” normalizes the exposure to 1 year of baseline operation (84x10<sup>20</sup> POT-kt).
- I always assume that the exposure is split evenly between neutrino and antineutrino running which is close to optimal until the  $\delta_{CP}$ /hierarchy combination is known. Once we have data, we can re-optimize.

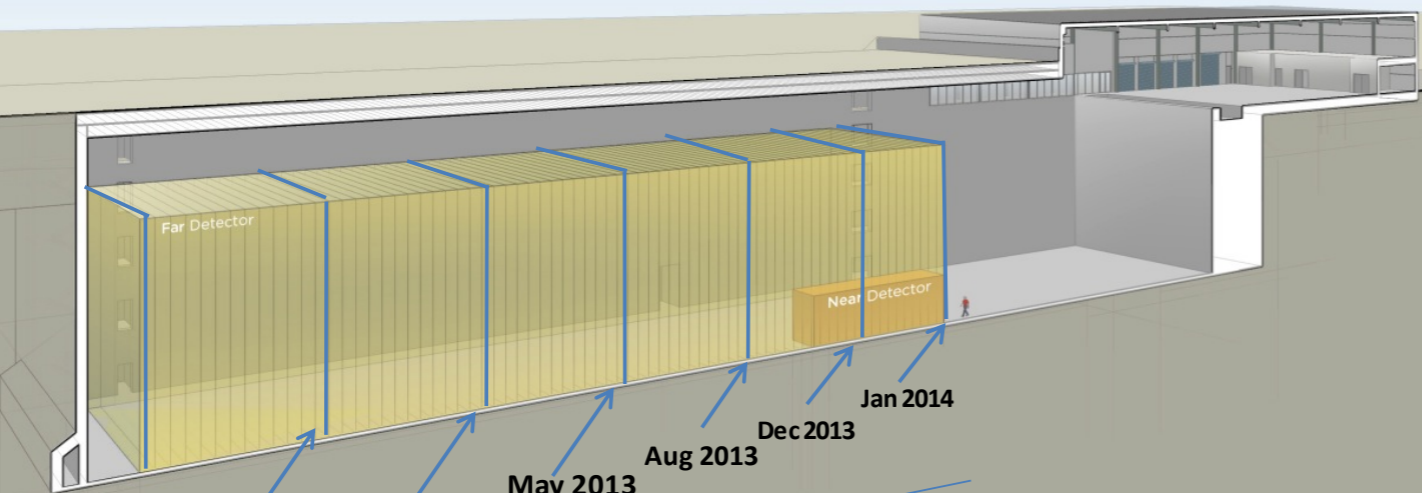
Completed NOvA Laboratory, Ash River, MN



NOvA Module Factory at University of Minnesota



NOvA Prototype Near Detector in NuMI and Booster Neutrino beams



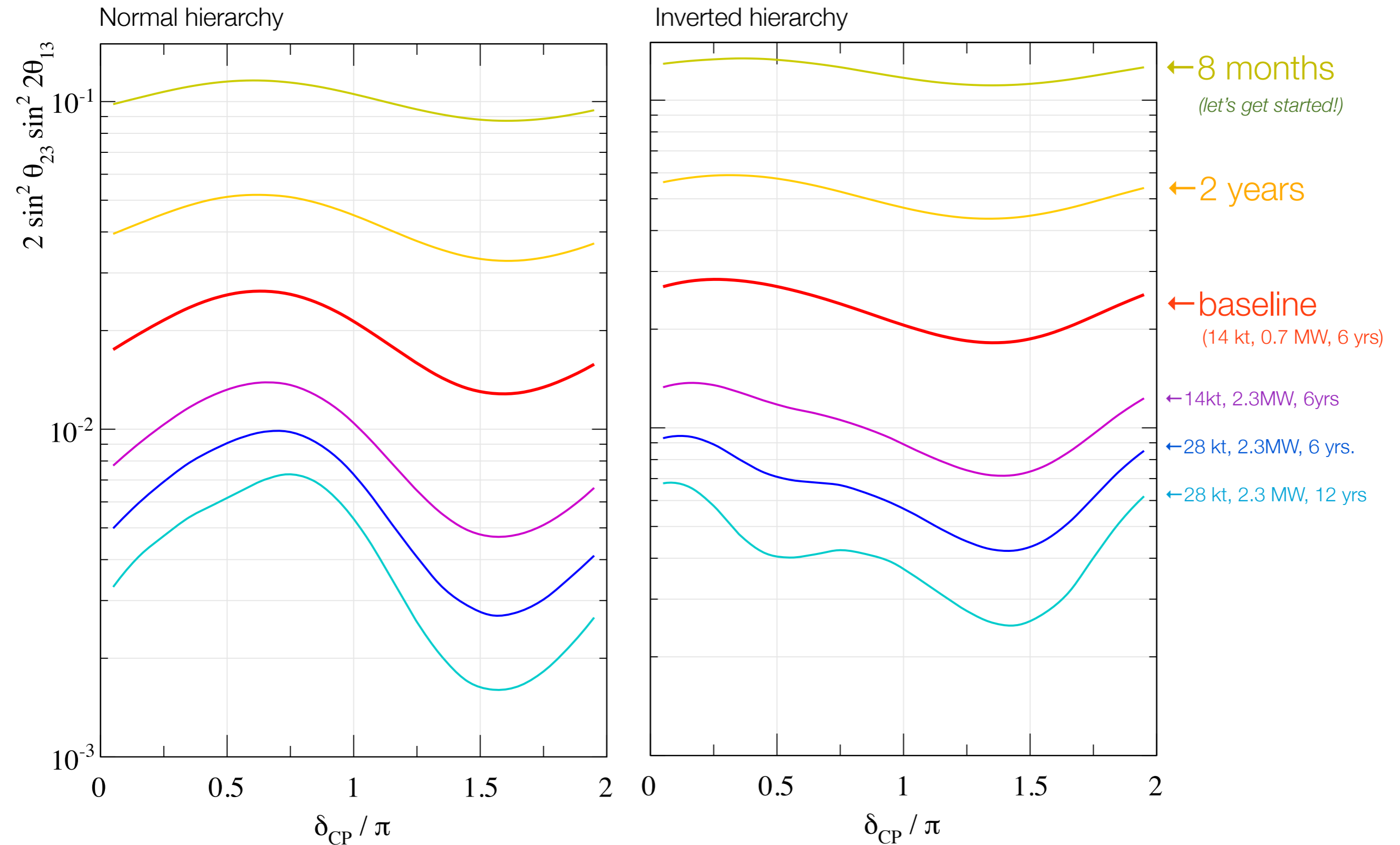
Nov 2012 Jan 2013 May 2013 Aug 2013 Dec 2013 Jan 2014

Beam off Mar 2012 - Feb 2013

Beam returns Feb 2013 reaches 700 kW ~ Aug 2013

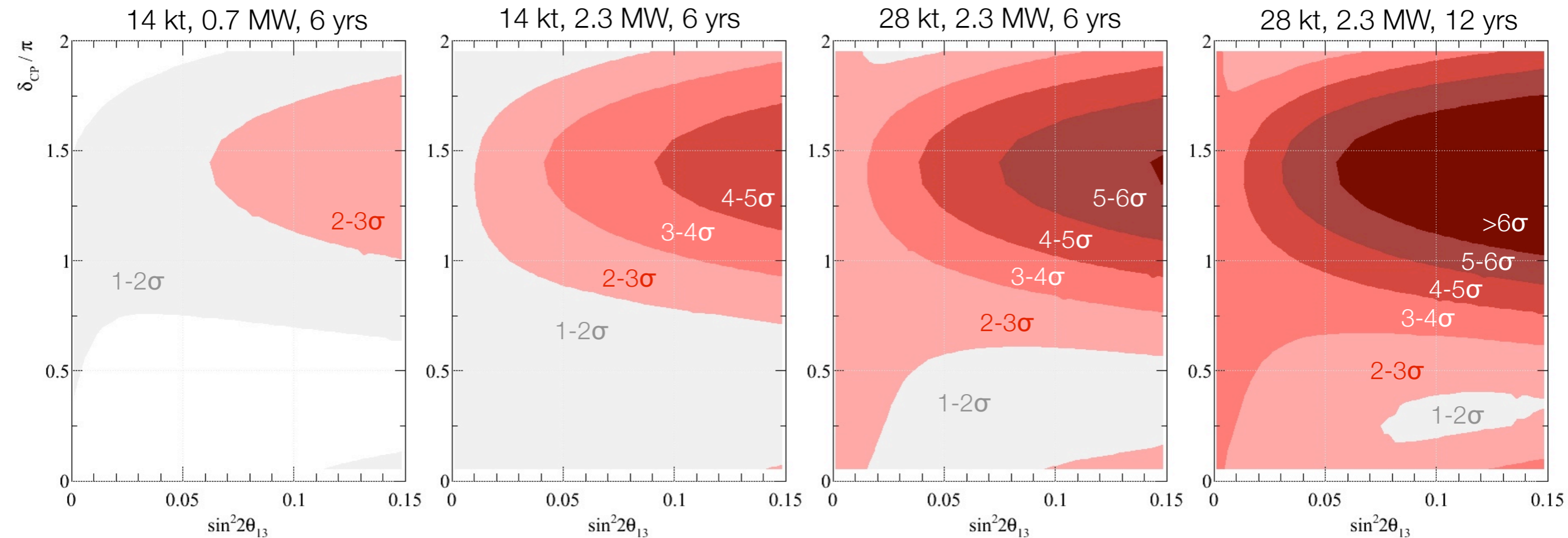
Far detector construction schedule

# 3 $\sigma$ Sensitivity to $\sin^2 2\theta_{13} > 0$



$\nu_e / \bar{\nu}_e$  appearance in NOvA is statistics limited for all reasonable exposures  
 Can check T2K results with about 8 months of data  
 3 $\sigma$  sensitivity to T2K + MINOS best fit after 2 years

# Resolution of the Mass Hierarchy

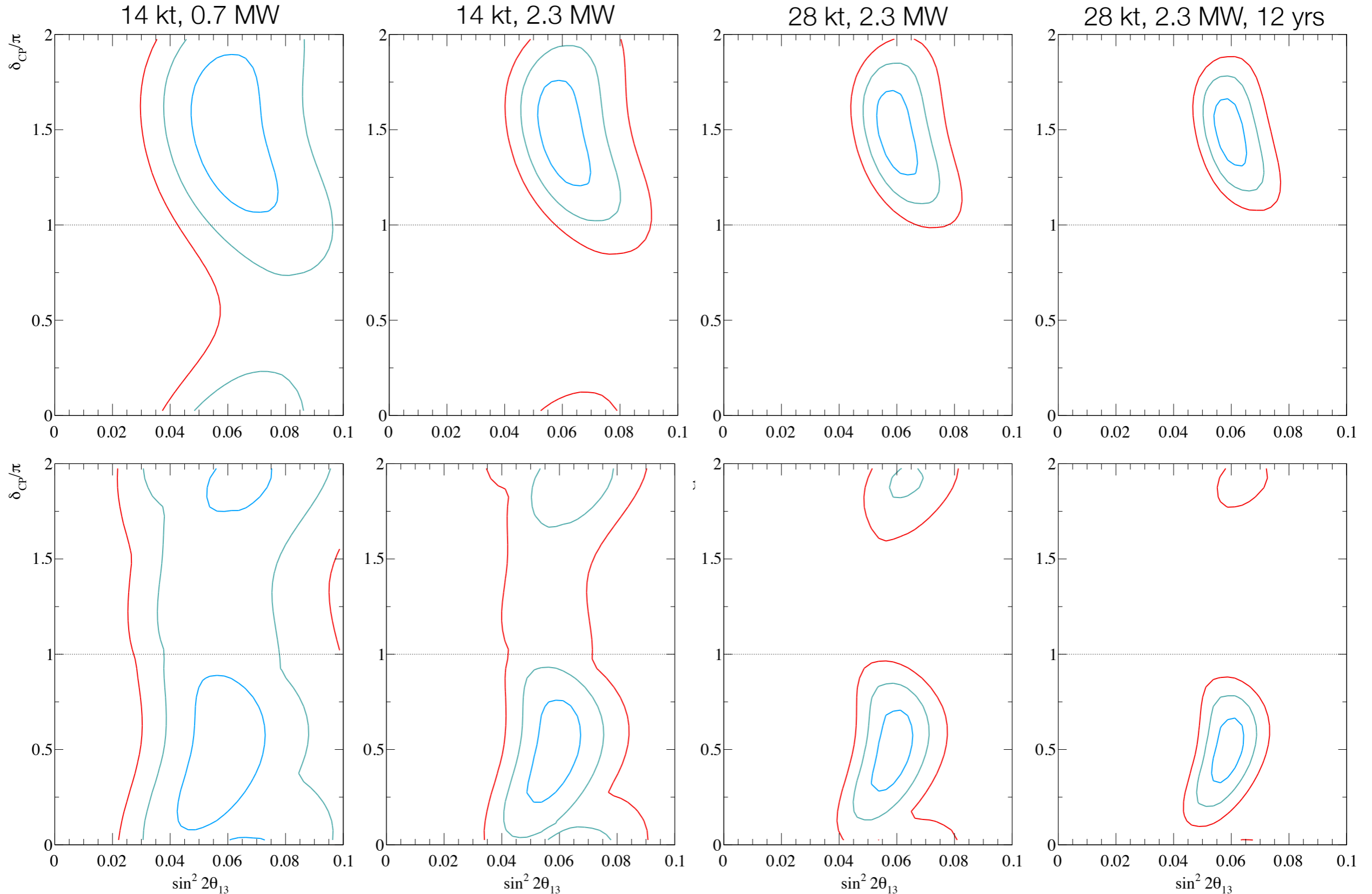


These calculations are for normal hierarchy.

Inverted hierarchy looks same but is reflected across  $\delta_{CP}=\pi$ .

Degeneracies affect only a small region in “wrong” half of  $\delta_{CP}$  space.

# 1, 2, 3 $\sigma$ Measurements of $\sin^2 2\theta_{13}$ and $\delta_{CP}$



For  $\delta_{CP}=3\pi/2$ , NH, NOvA could establish CPV at 3 $\sigma$  with larger exposure  
 For  $\delta_{CP}=\pi/2$ , NH, NOvA degeneracies do not allow measurement of CPV at 3 $\sigma$