Rules of the game

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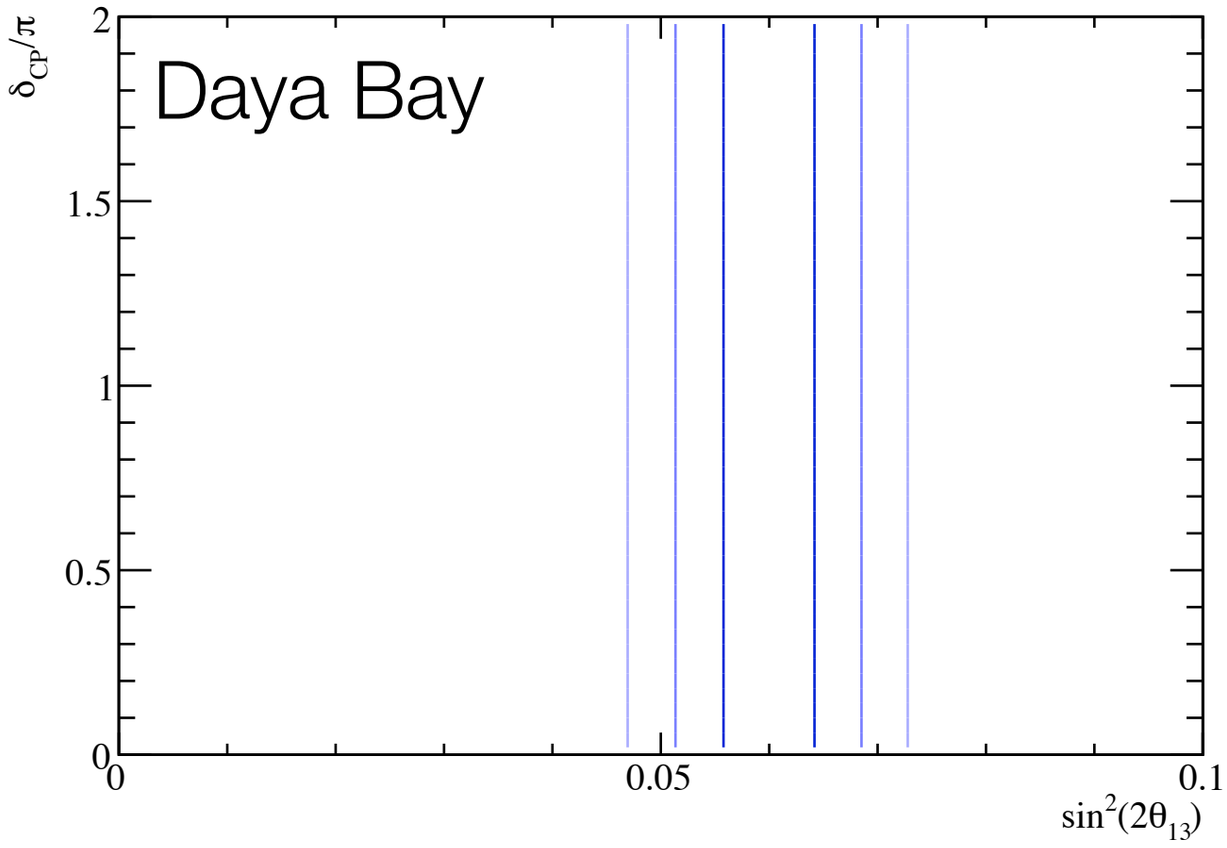
NOvA for lunch
11 FEB 2008

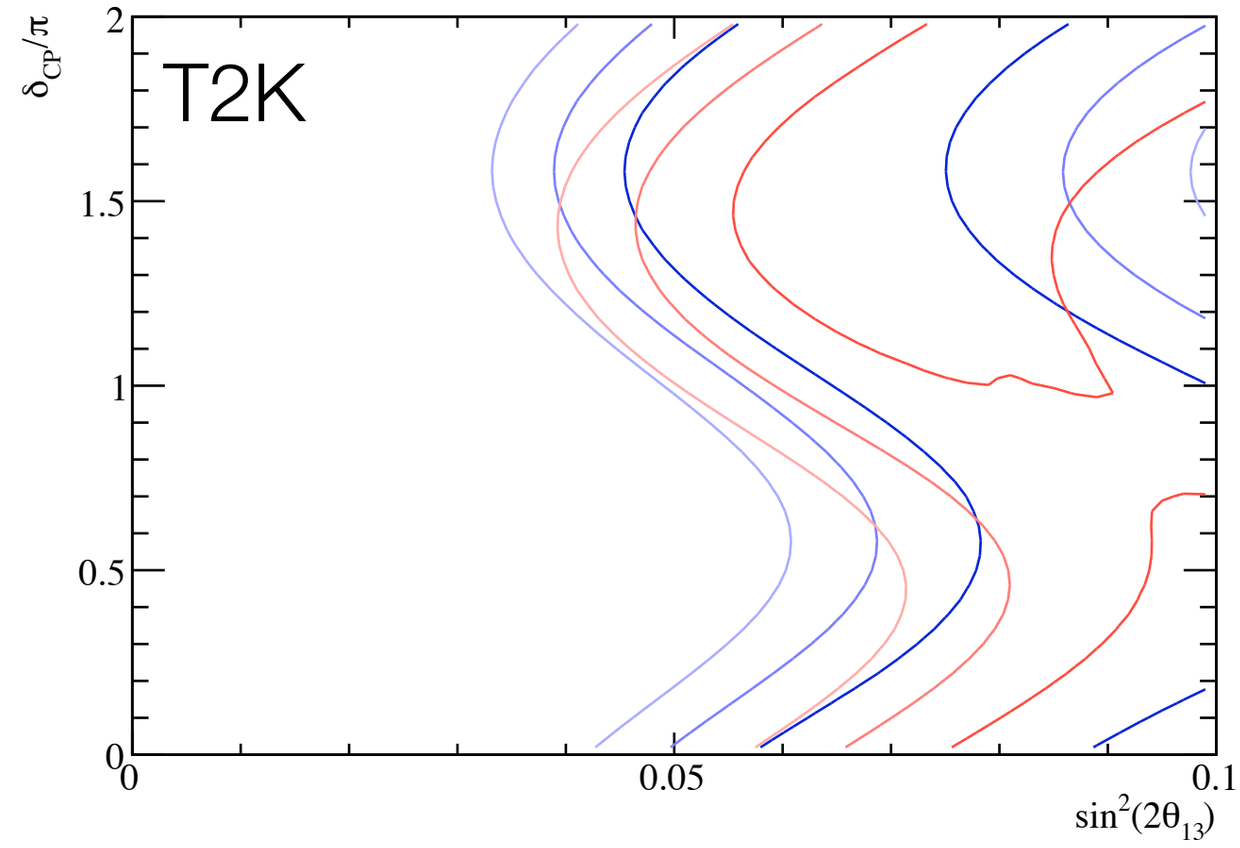
- I used GLoBES (*P. Huber, M. Lindner and W. Winter, arXiv:hep-ph/0407333, P. Huber, J. Kopp, M. Lindner, M. Rolinec, and W. Winter, arXiv:hep-ph/0701187*) to compute 1, 2, 3, sigma contours in ($\sin^2 2\theta_{13}$ - δ_{CP}) for Daya Bay, T2K, and NOVA. I also used combinations Daya Bay+T2K and Daya Bay+T2K +NOvA
- Input Δm^2_{23}=+2.5x10^{-3} eV^2, Δm^2_{12}=+7.6x10^{-5} eV^2, θ_{23}=45°, θ_{12}=35°
- Allowed $\sin^2 2\theta_{23}$ to vary, constrained by T2K and NOvA ν_μ disappearance measurements
- Test points $\sin^2 2\theta_{13}$ x δ_{CP} = (0.06, 0.03, 0.01) x ($3\pi/2$, $\pi/2$)
- *Daya Bay:* 80 tons at L = 1.7 km x 17 GW x 3 years, 0.38% syst. error
- *T2K:* 22.5 kt at L = 295 km x 770 kW x 5 years, 5% syst. error
- *NOvA:* 15 kt at L = 810 km x 700 kW x 3ν+3$\bar{\nu}$ years, 5% syst. error
- Used latest NOvA efficiency (35%)
- Confirmed 90% sensitivity curves for Daya Bay and T2K

Full set of plots follow. Here's a summary

$\sin^2 2\theta_{13}$	δ_{CP}	Experiments	Hierarchy	Fraction of δ (3σ / 2σ)	Notes
0.06	$3\pi/2$	DB+T2K	-	0% / 40%	
		DB+T2K+NOvA	$> 2\sigma$	35% / 47%	1σ hints at CPV
	$\pi/2$	DB+T2K	-	0% / 10%	
		DB+T2K+NOvA	$> 1\sigma$	0% / 32%	Normal hierarchy $\rightarrow$ improved
0.03	$3\pi/2$	DB+T2K	-	0% / 30%	
		DB+T2K+NOvA	$> 1\sigma$	30% / 45%	
	$\pi/2$	DB+T2K	-	0% / 0%	
		DB+T2K+NOvA	$> 1\sigma$	0% / 30%	
0.01	$3\pi/2$	DB+T2K	-	0% / 0%	
		DB+T2K+NOvA	$> 1\sigma$	0% / 35%	
	$\pi/2$	DB+T2K	-	0% / 0%	T2K does not confirm reactor
		DB+T2K+NOvA	-	0% / 15%	Reactor confirmed at $> 2\sigma$

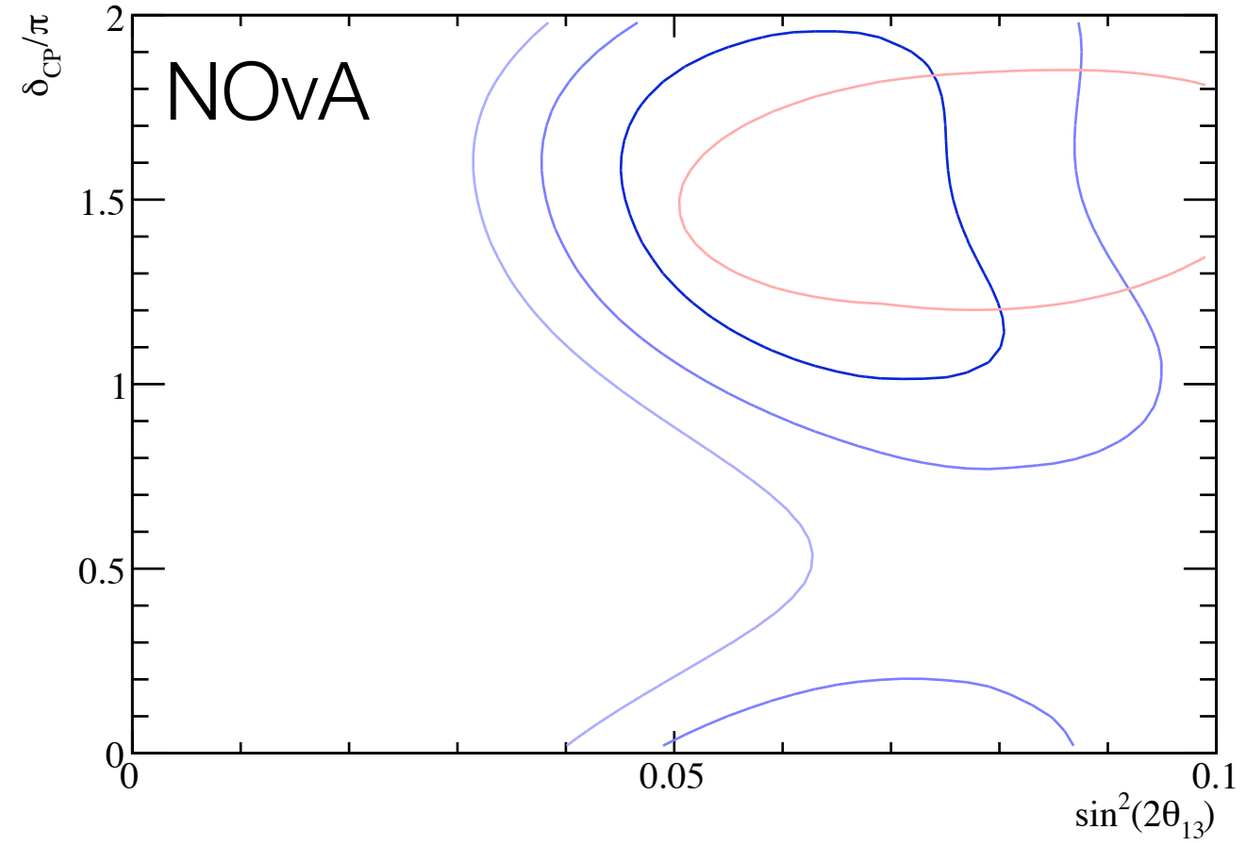
- Only in worst case (0.01,π/2) does NOvA fail to provide some information about hierarchy. In that worst case, NOvA is required to confirm report from reactor.
- Only possible to see hints of CPV when NOvA is added
- Only learn about δ_{CP} at >3 sigma when NOvA is added
- Always learn something about δ_{CP} at 2 sigma when NOvA is added





$\sin^2 2\theta_{13} = 0.06$, $\delta_{CP} = 3\pi/2$, normal hierarchy

Three experiments taken alone
Blue: Normal hierarchy
Red: Inverted hierarchy
From outside in: 3, 2, 1 sigma contours



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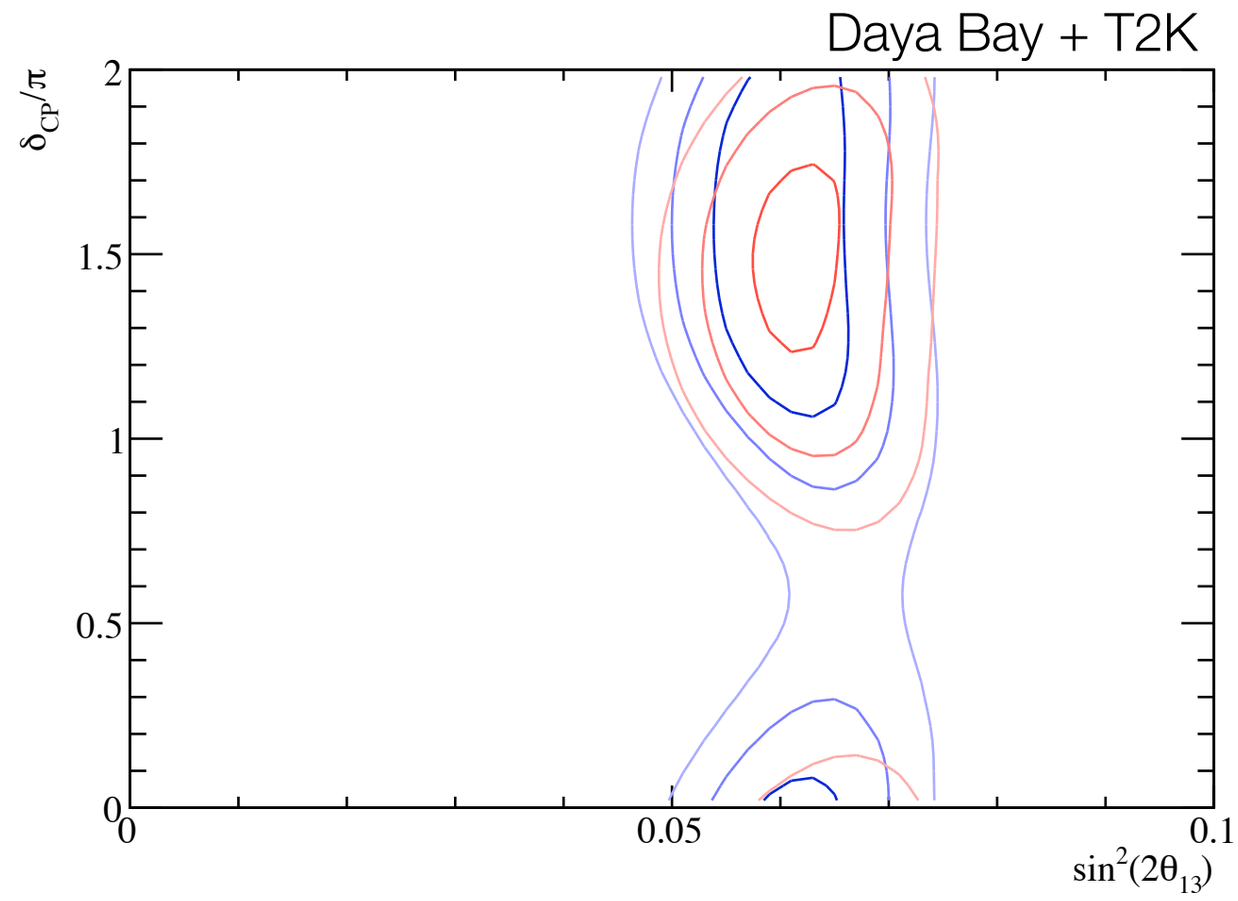
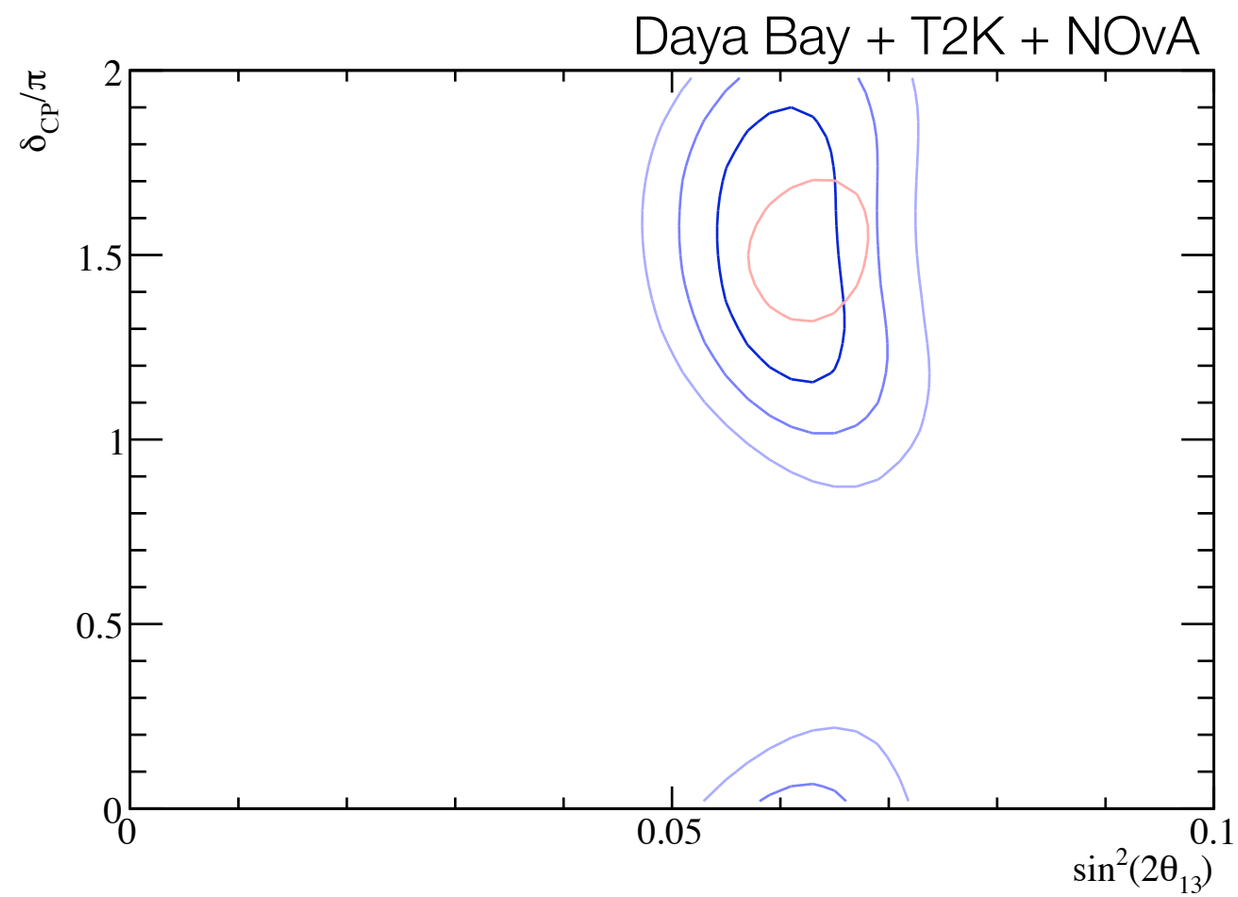


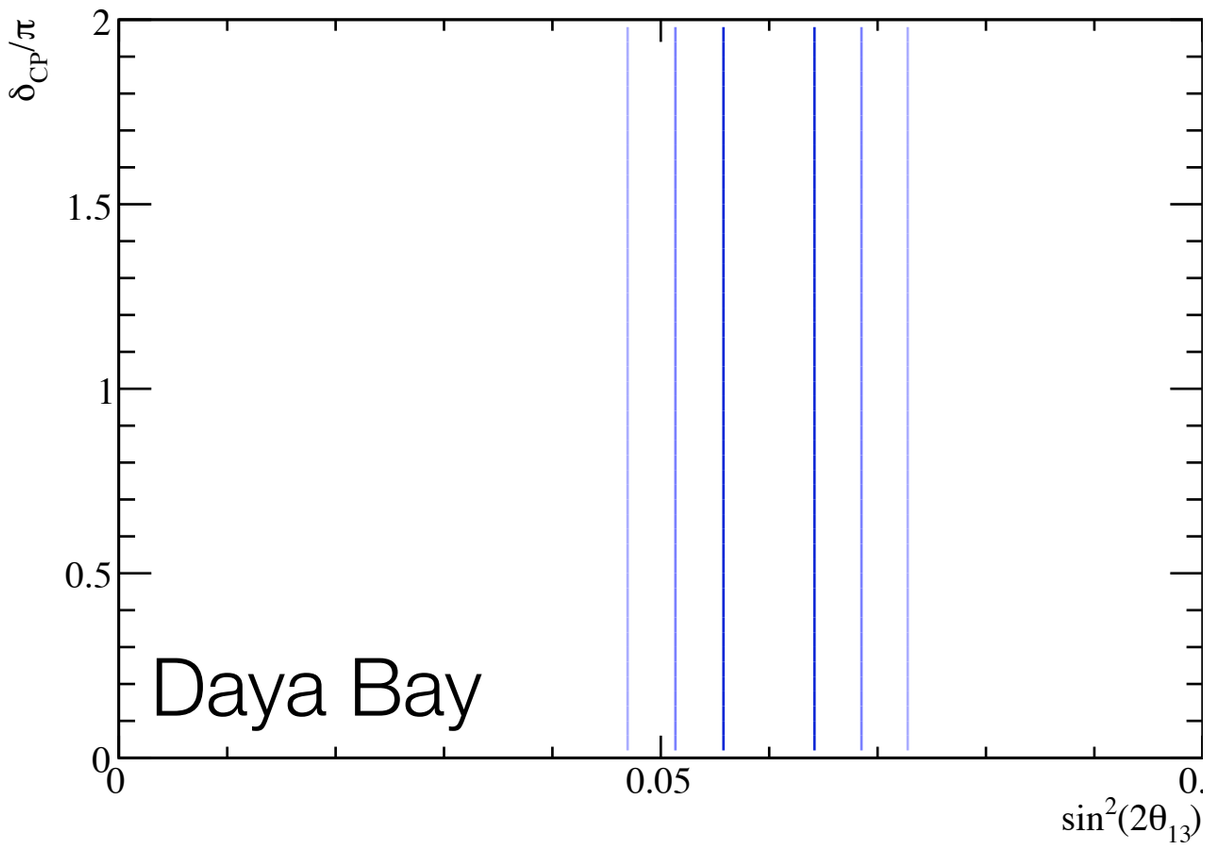
<u>*Daya Bay + T2K*</u>

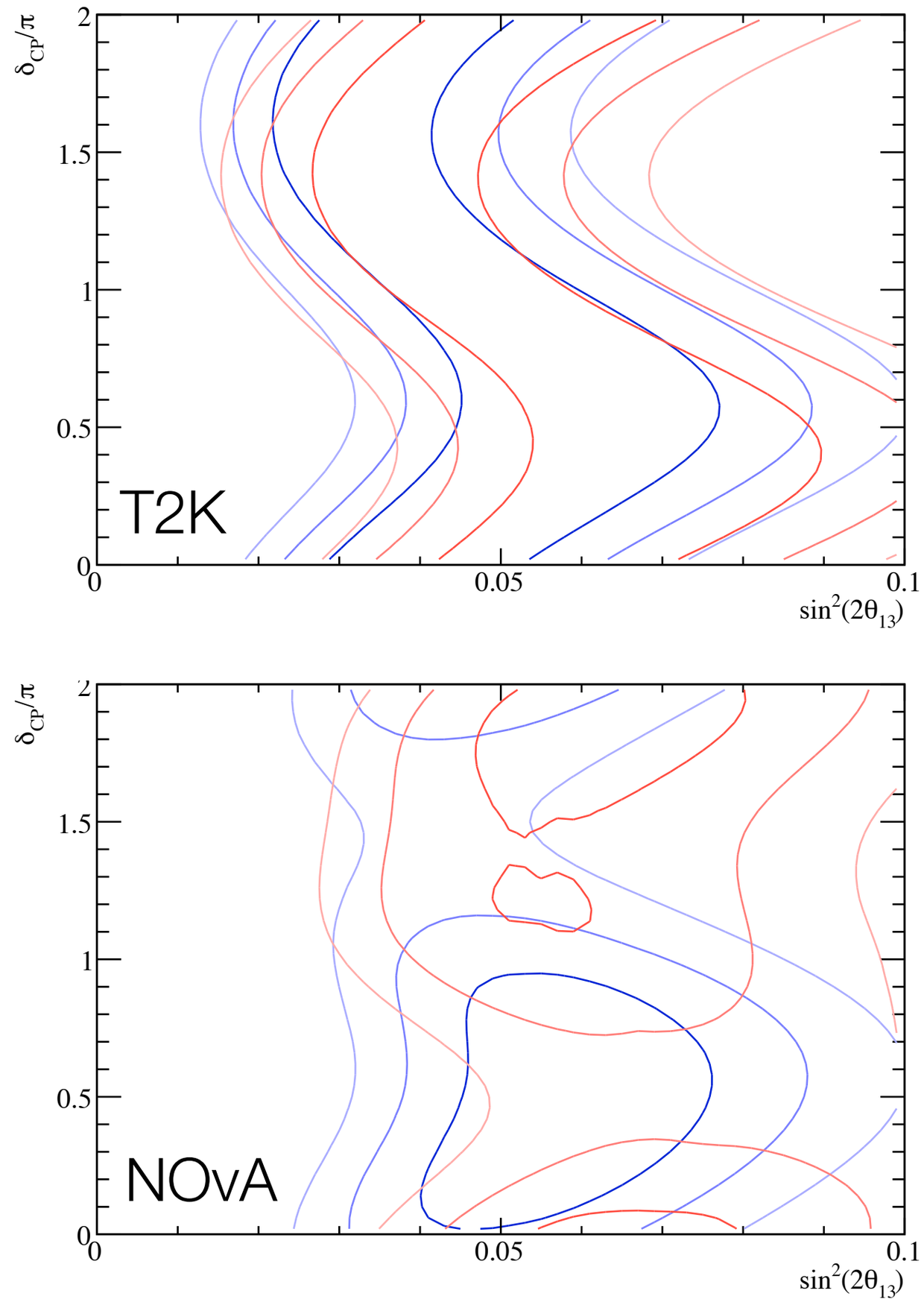
- No sensitivity to hierarchy
- No sensitivity to CP phase at >3 sigma.
- $0.1 < \delta/\pi < 0.9$ disfavored at 2 sigma (40% of space)

<u>*Daya Bay + T2K + NOvA*</u>

- Hierarchy determined at >2 sigma.
- Hints of CP violation at 1 sigma
- $0.9 < \delta/\pi < 0.2$ disfavored at 3 sigma (35% of space)
- $1.0 < \delta/\pi < 0.05$ disfavored at 2 sigma (47% of space)







$\sin^2 2\theta_{13} = 0.06$, $\delta_{CP} = \pi/2$, normal hierarchy

Three experiments taken alone
Blue: Normal hierarchy
Red: Inverted hierarchy
From outside in: 3, 2, 1 sigma contours

$\sin^2 2\theta_{13} = 0.06$, $\delta_{CP} = \pi/2$, normal hierarchy

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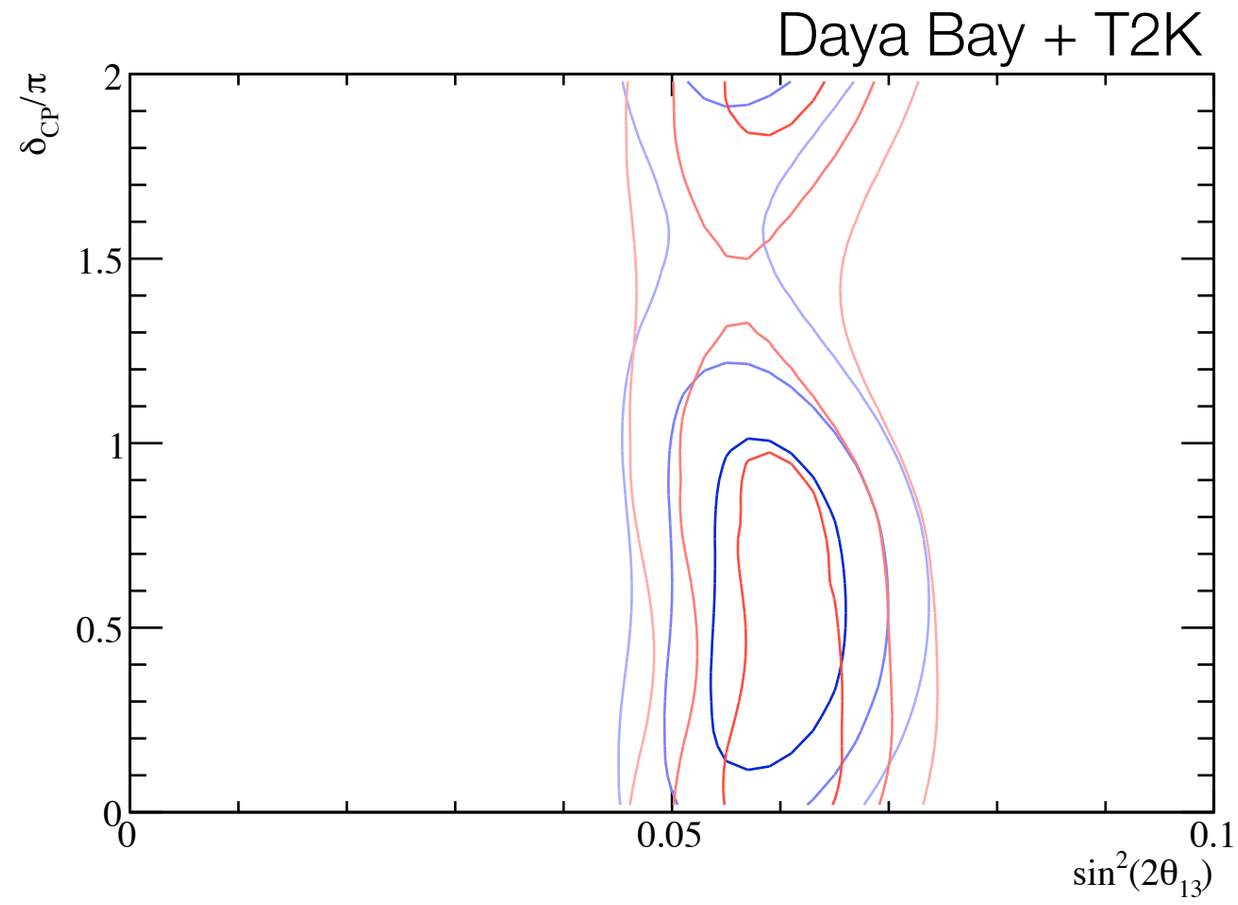
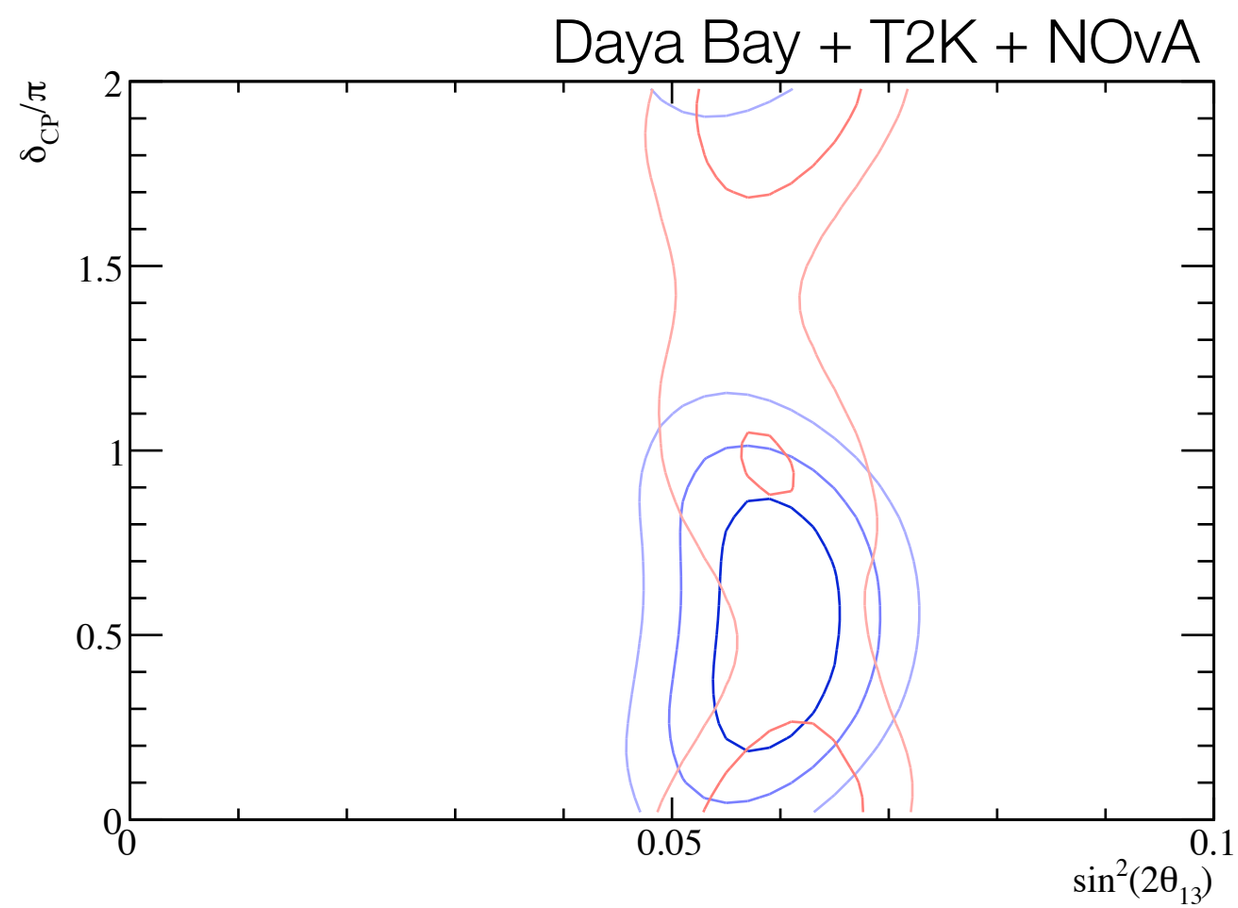


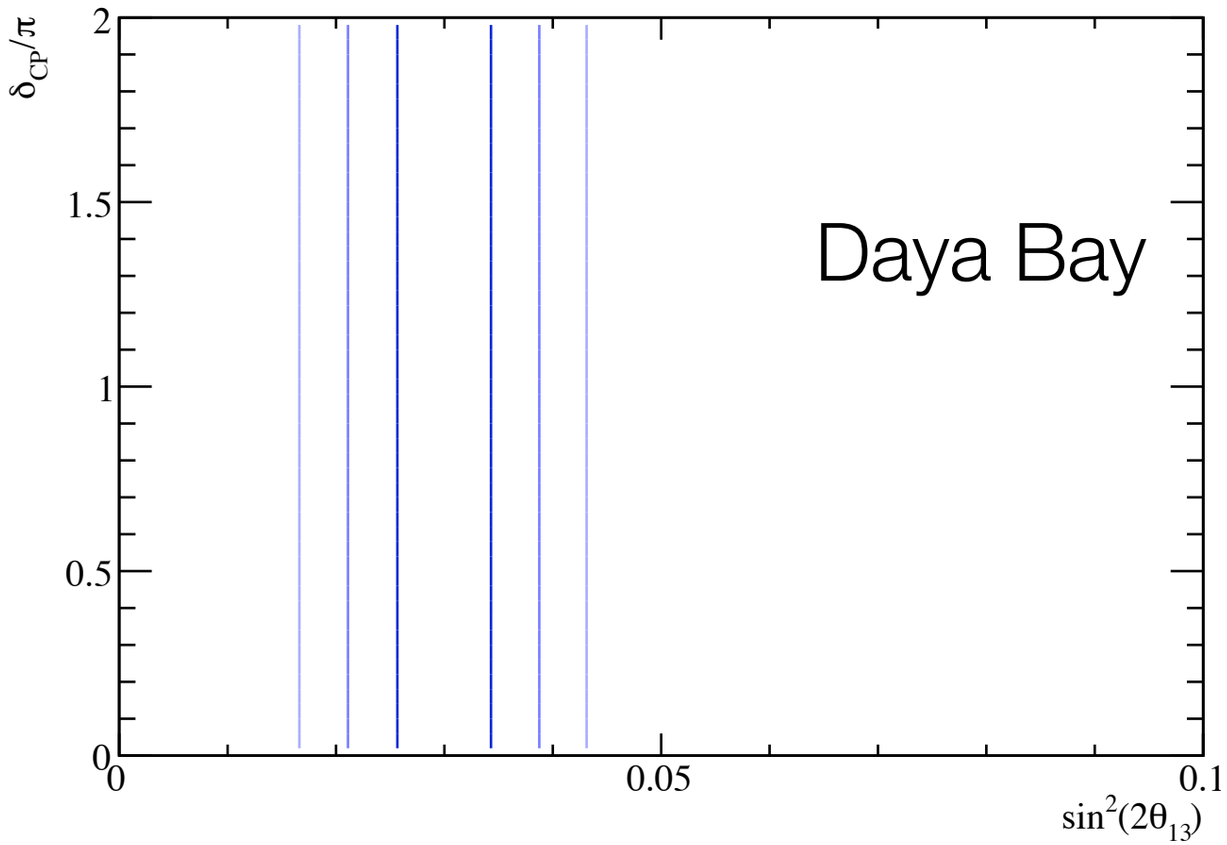
<u>*Daya Bay + T2K*</u>

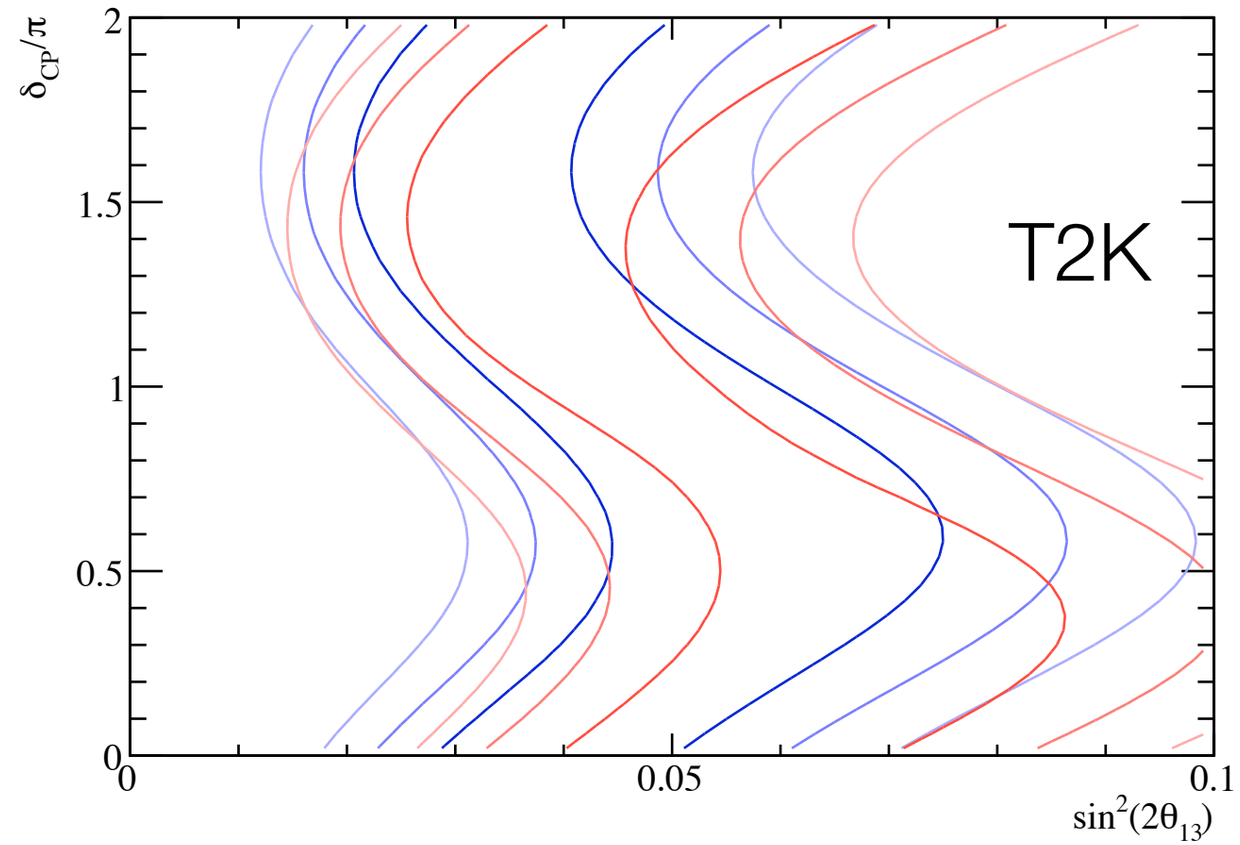
- No sensitivity to hierarchy
- No sensitivity to CP phase at >3 sigma.
- $1.3 < \delta/\pi < 1.5$ disfavored at 2 sigma (10% of space)

<u>*Daya Bay + T2K + NOvA*</u>

- Inverted hierarchy disfavored by >1 sigma
- $1.05 < \delta/\pi < 1.7$ disfavored at 2 sigma (32% of space)
- If you're willing to accept the normal hierarchy, CP limits much improved







$\sin^2 2\theta_{13} = 0.03$, $\delta_{CP} = 3\pi/2$, normal hierarchy

Three experiments taken alone
Blue: Normal hierarchy
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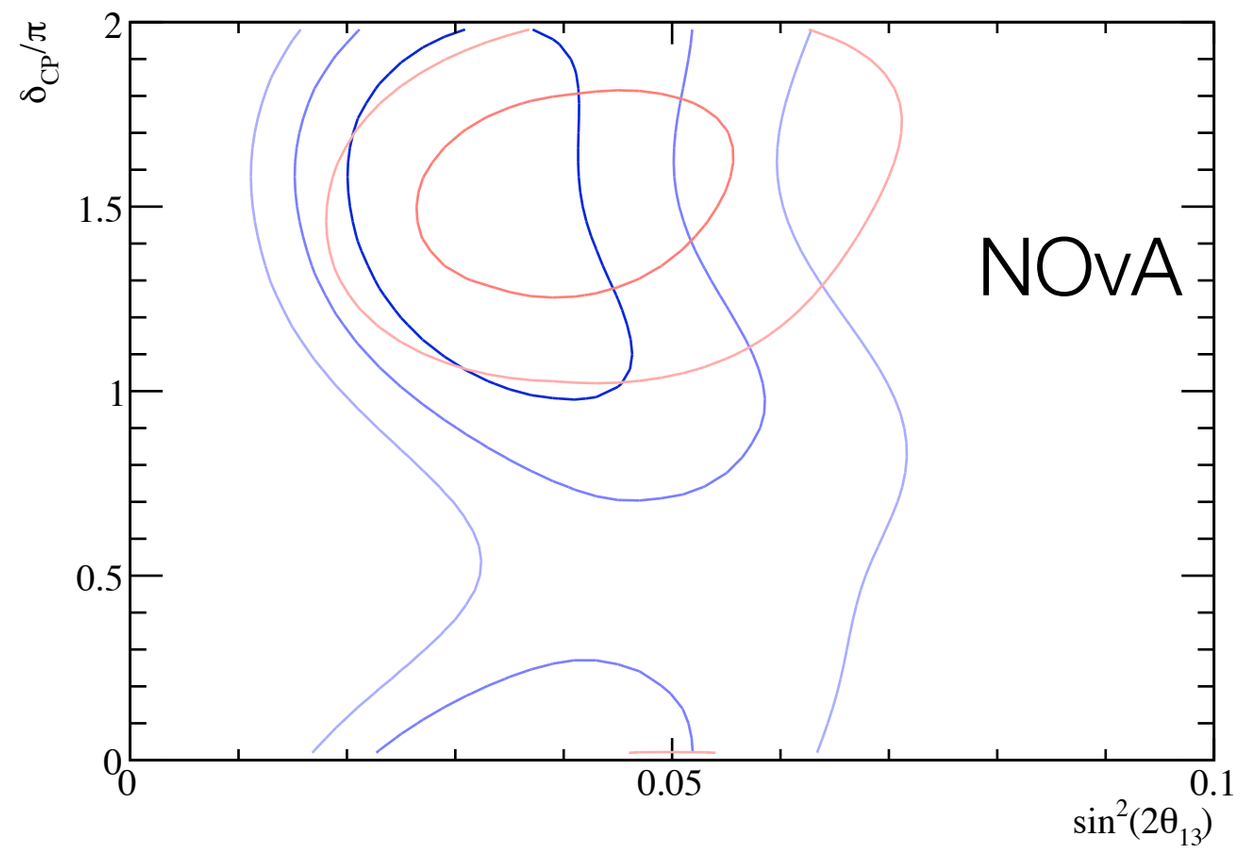
From outside in: 3, 2, 1 sigma contours



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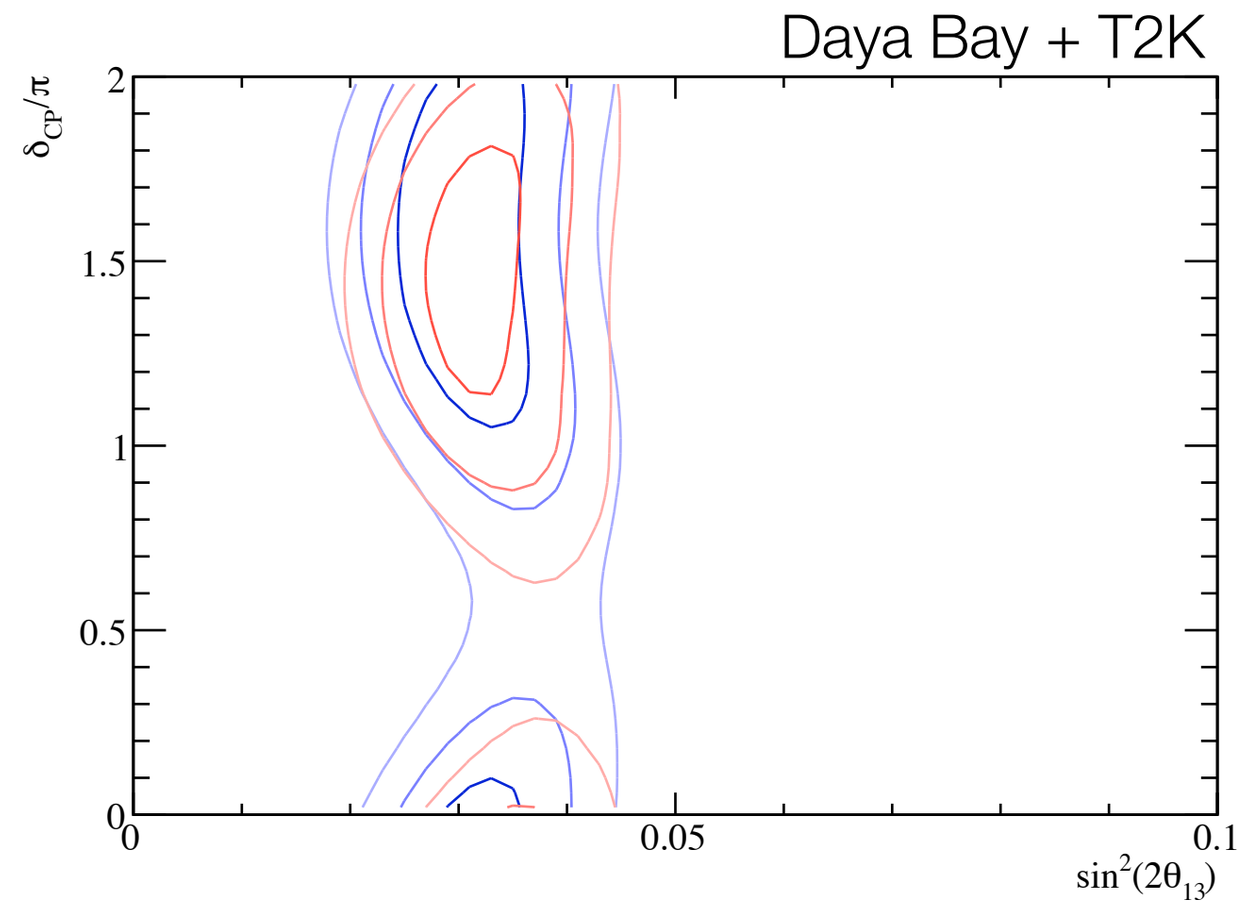
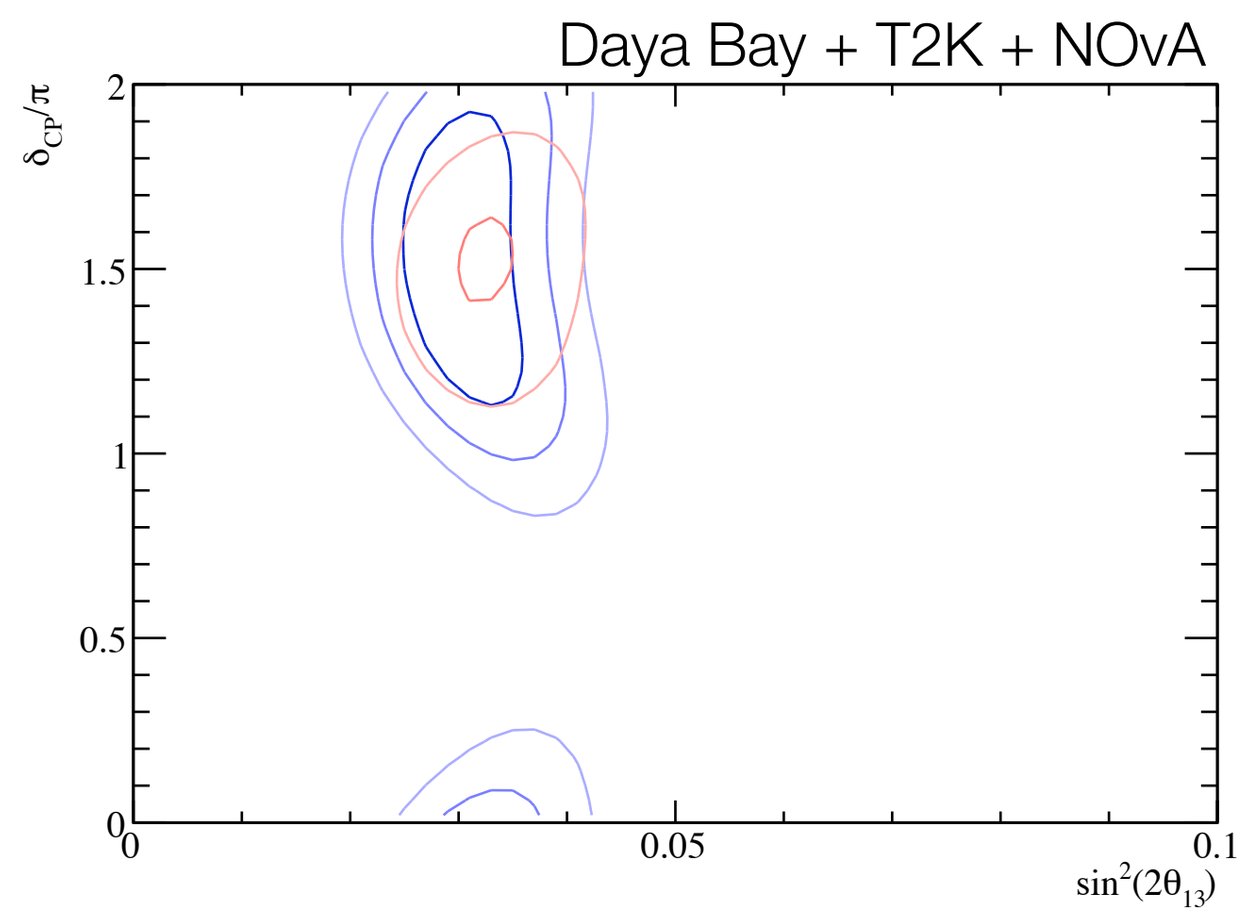


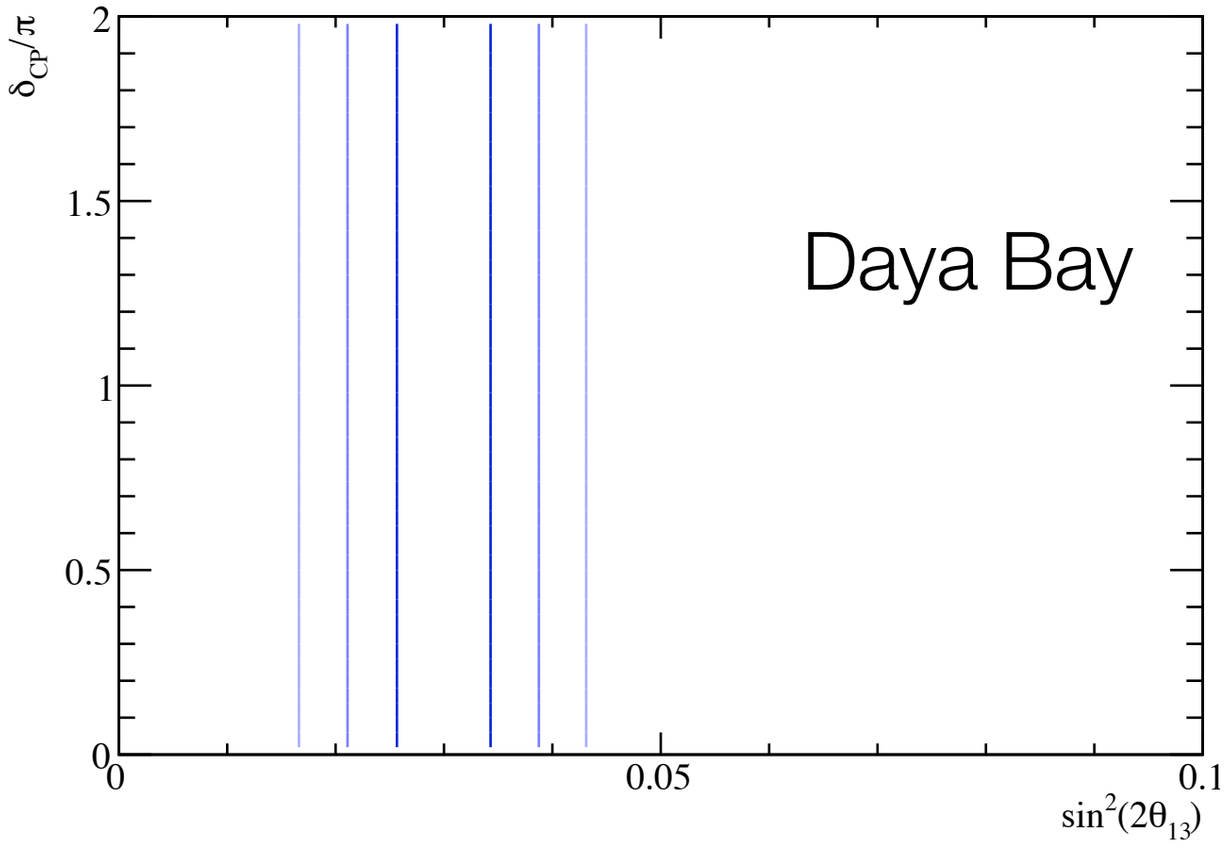
<u>*Daya Bay + T2K*</u>

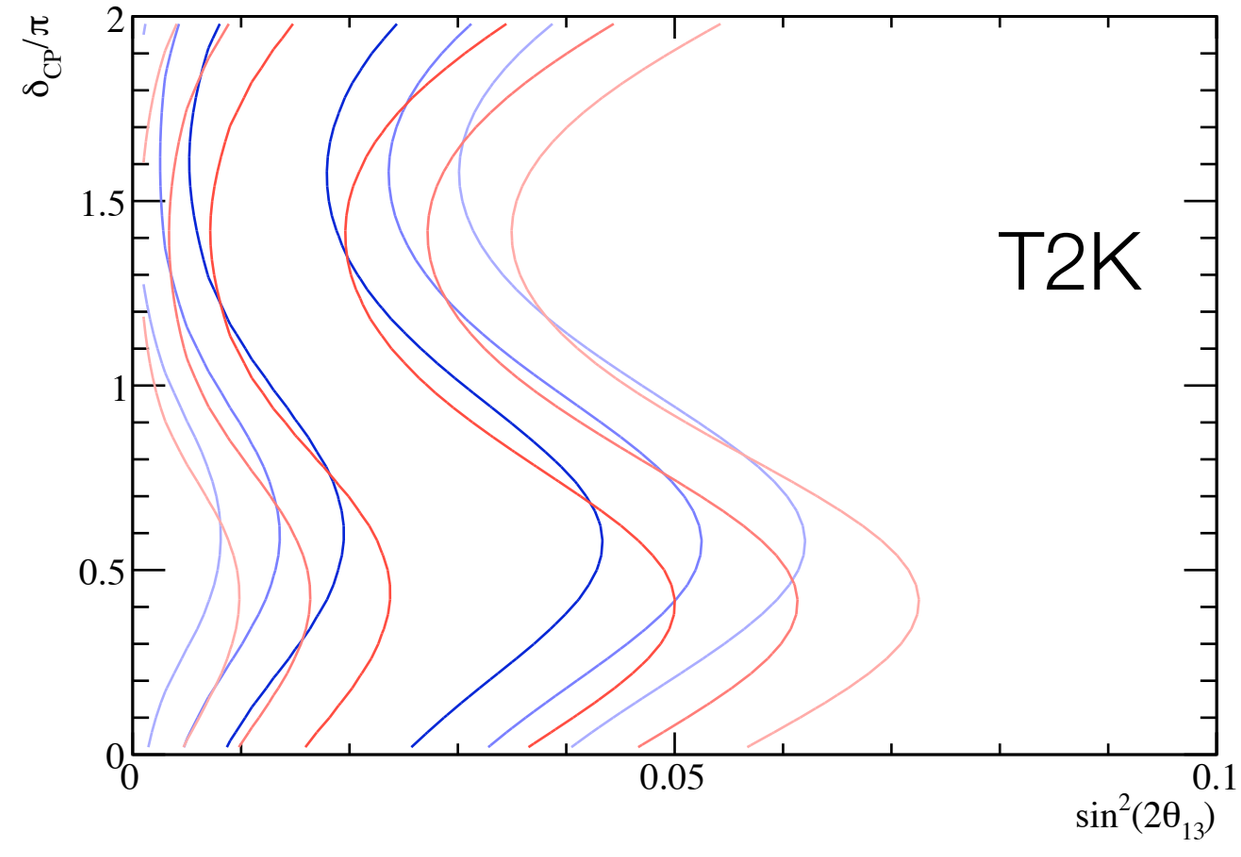
- No sensitivity to hierarchy
- No sensitivity to CP phase at >3 sigma.
- $0.8 < \delta/\pi < 0.1$ disfavored at 2 sigma (35% of space)

<u>*Daya Bay + T2K + NOvA*</u>

- Inverted hierarchy disfavored by >1 sigma
- $0.2 < \delta/\pi < 0.8$ disfavored at 3 sigma (30% of space)
- $0.1 < \delta/\pi < 1.0$ disfavored at 2 sigma (45% of space)







$\sin^2 2\theta_{13} = 0.03$, $\delta_{CP} = \pi/2$,
normal hierarchy

Three experiments taken alone
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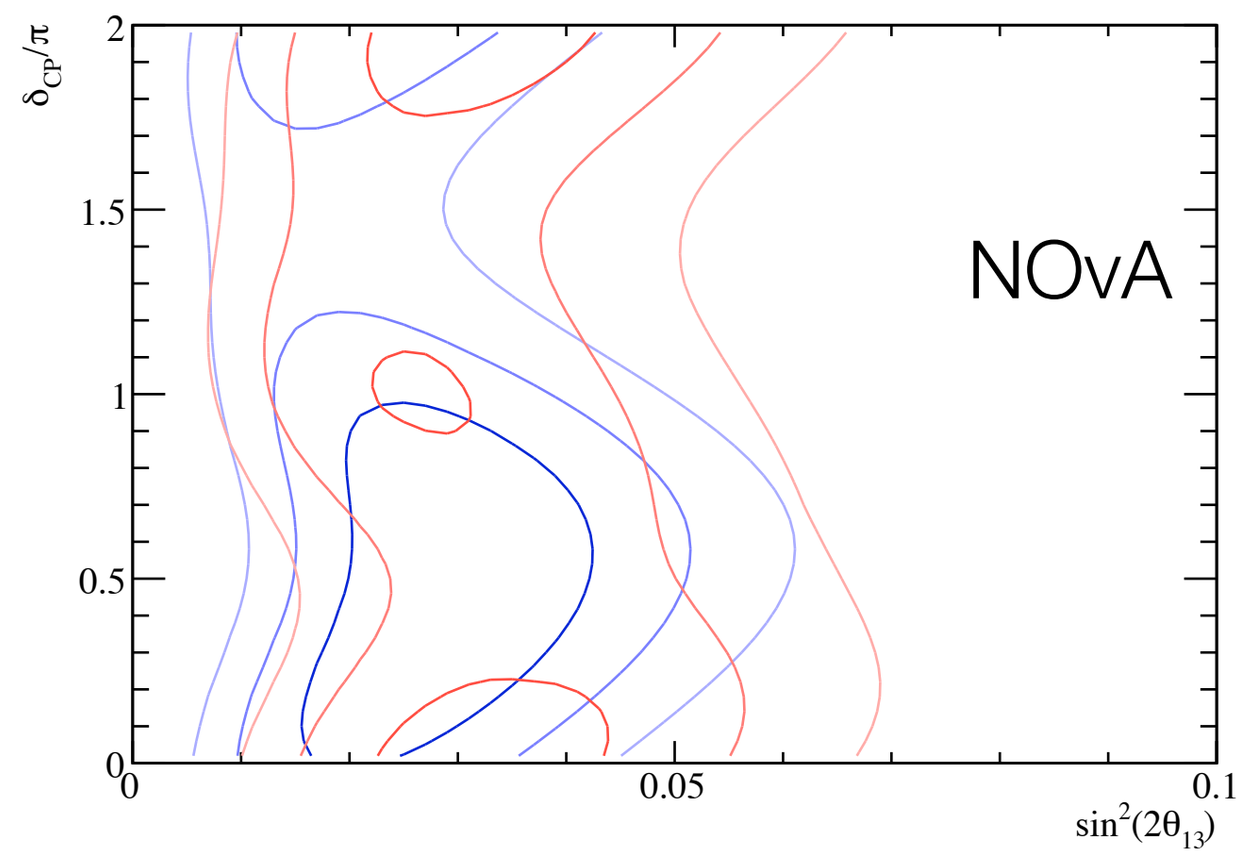

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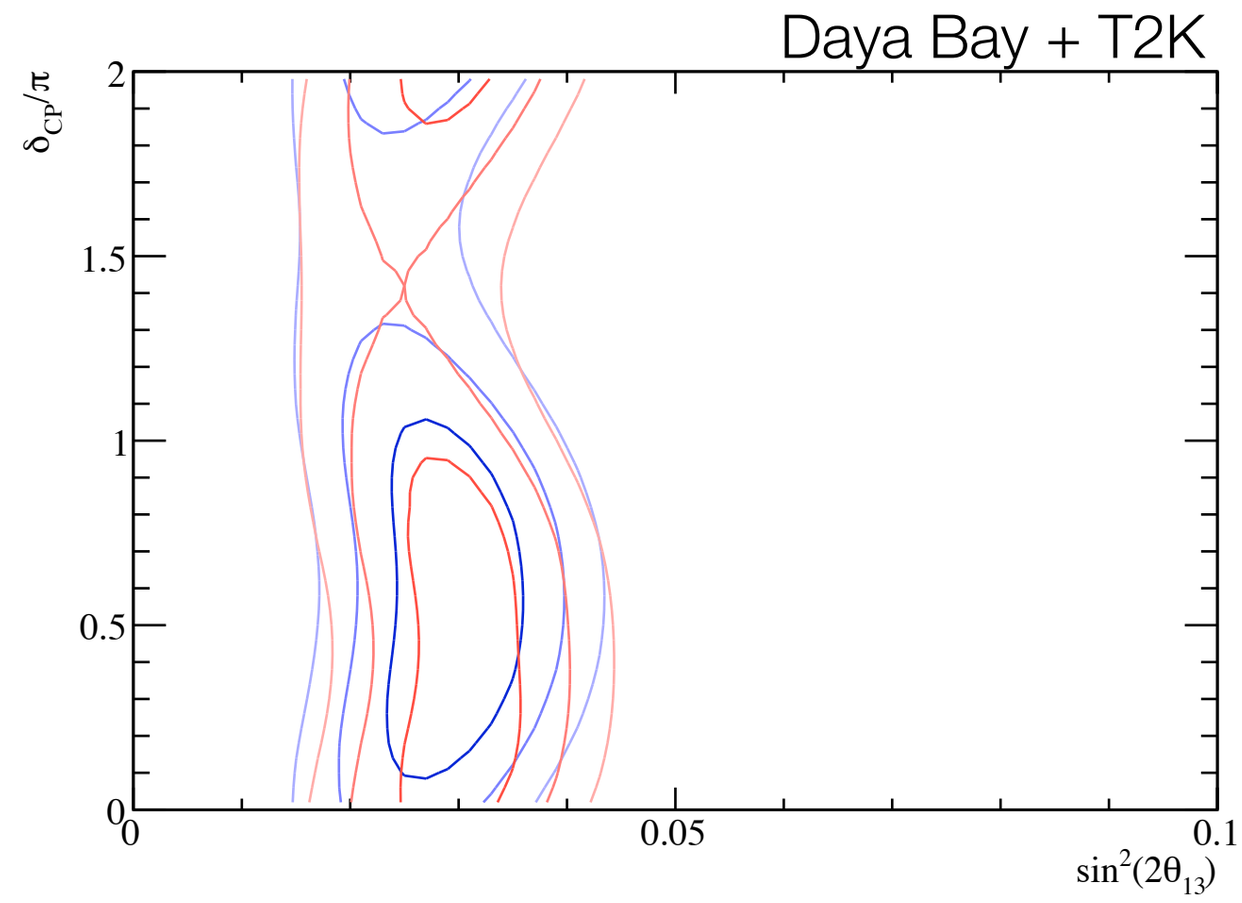
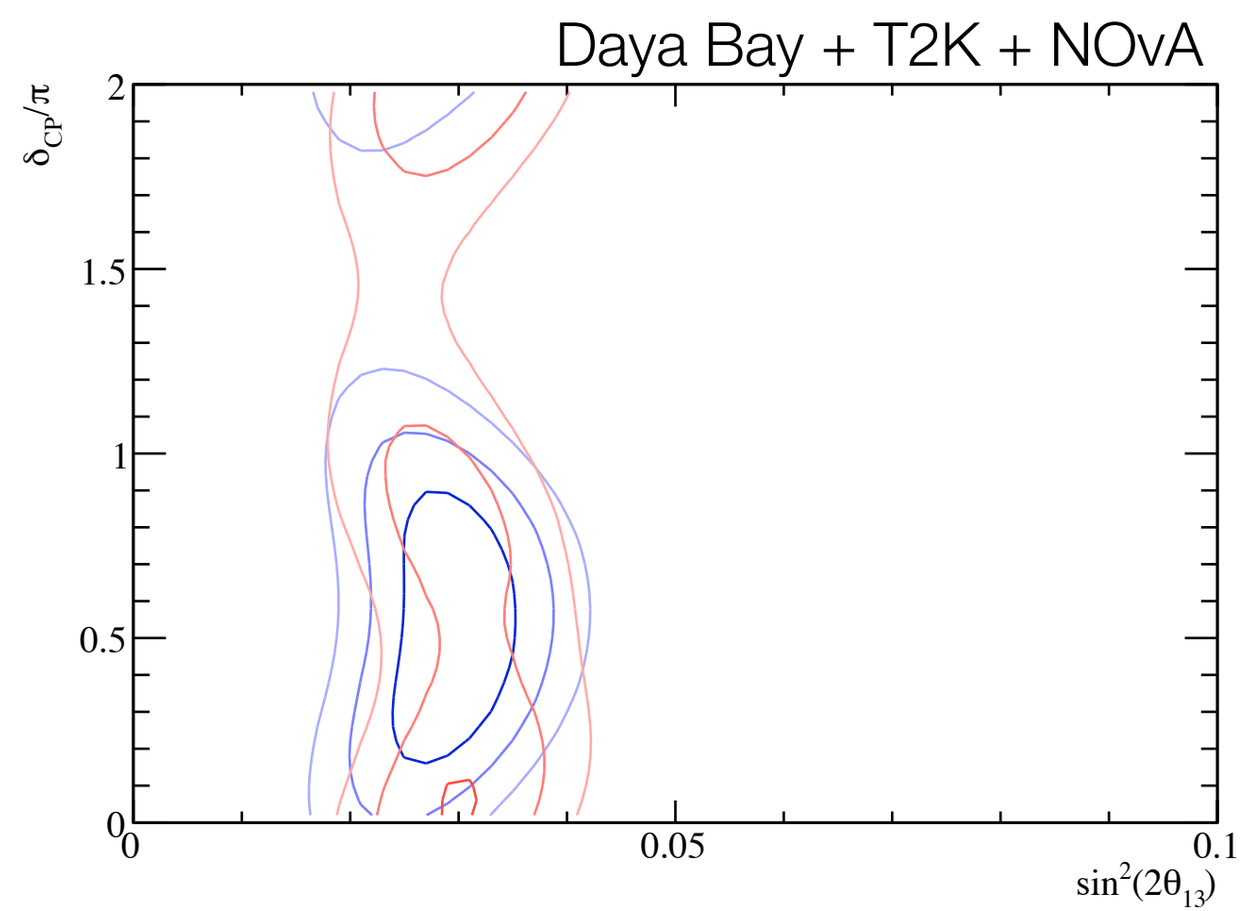


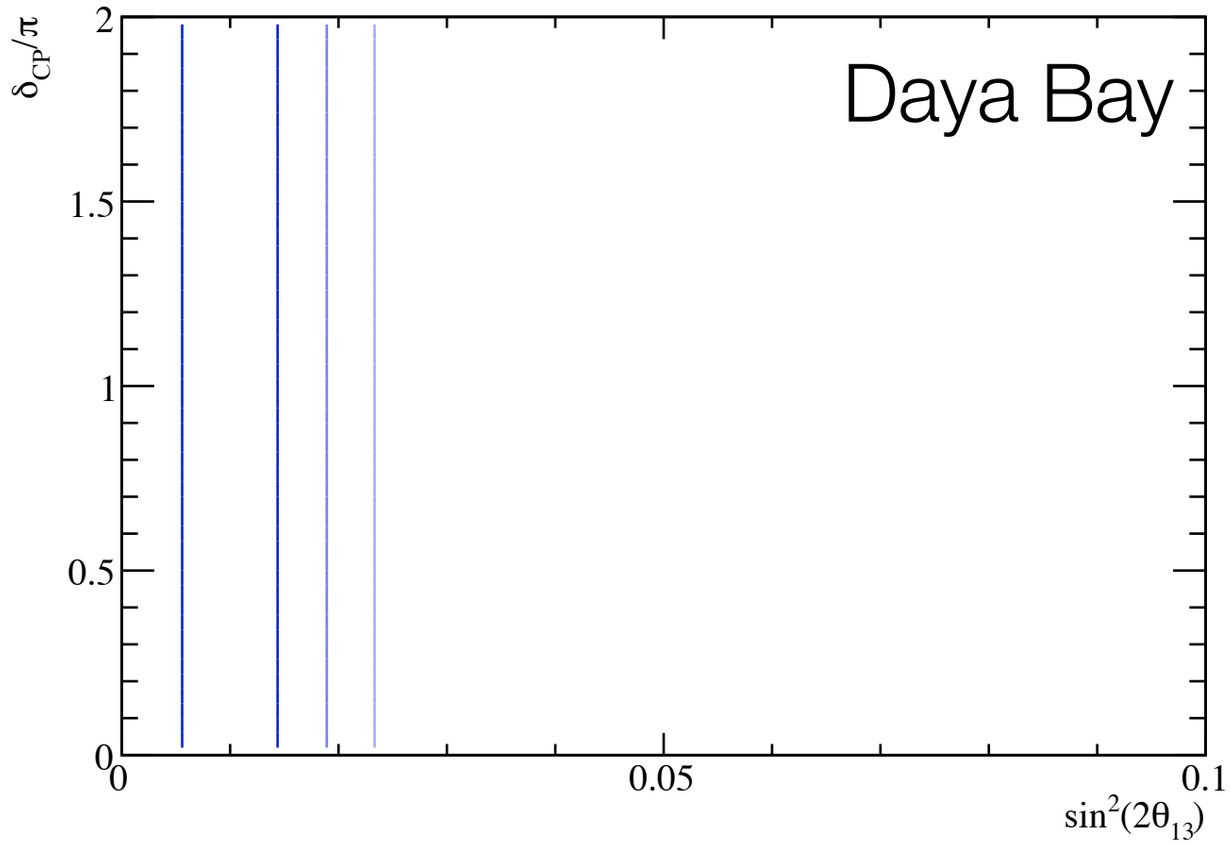
<u>*Daya Bay + T2K*</u>

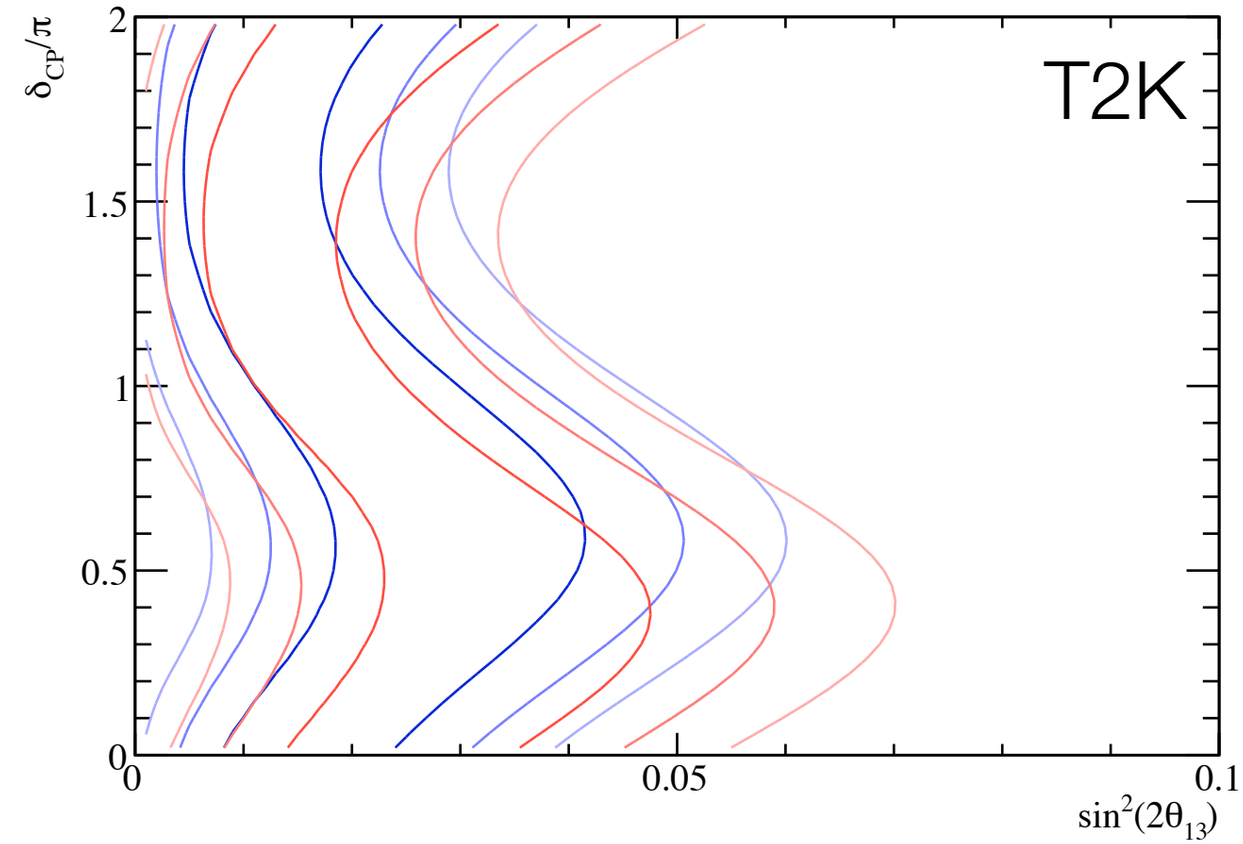
- No sensitivity to hierarchy
- No sensitivity to CP phase at >3 sigma.
- No sensitivity to CP phase at >2 sigma.

<u>*Daya Bay + T2K + NOvA*</u>

- Small region for inverted hierarchy allowed at 1 sigma
- No sensitivity to CP phase at >3 sigma
- $1.1 < \delta/\pi < 1.7$ disfavored at 2 sigma (30% of space)







$\sin^2 2\theta_{13} = 0.01$, $\delta_{CP} = 3\pi/2$, normal hierarchy

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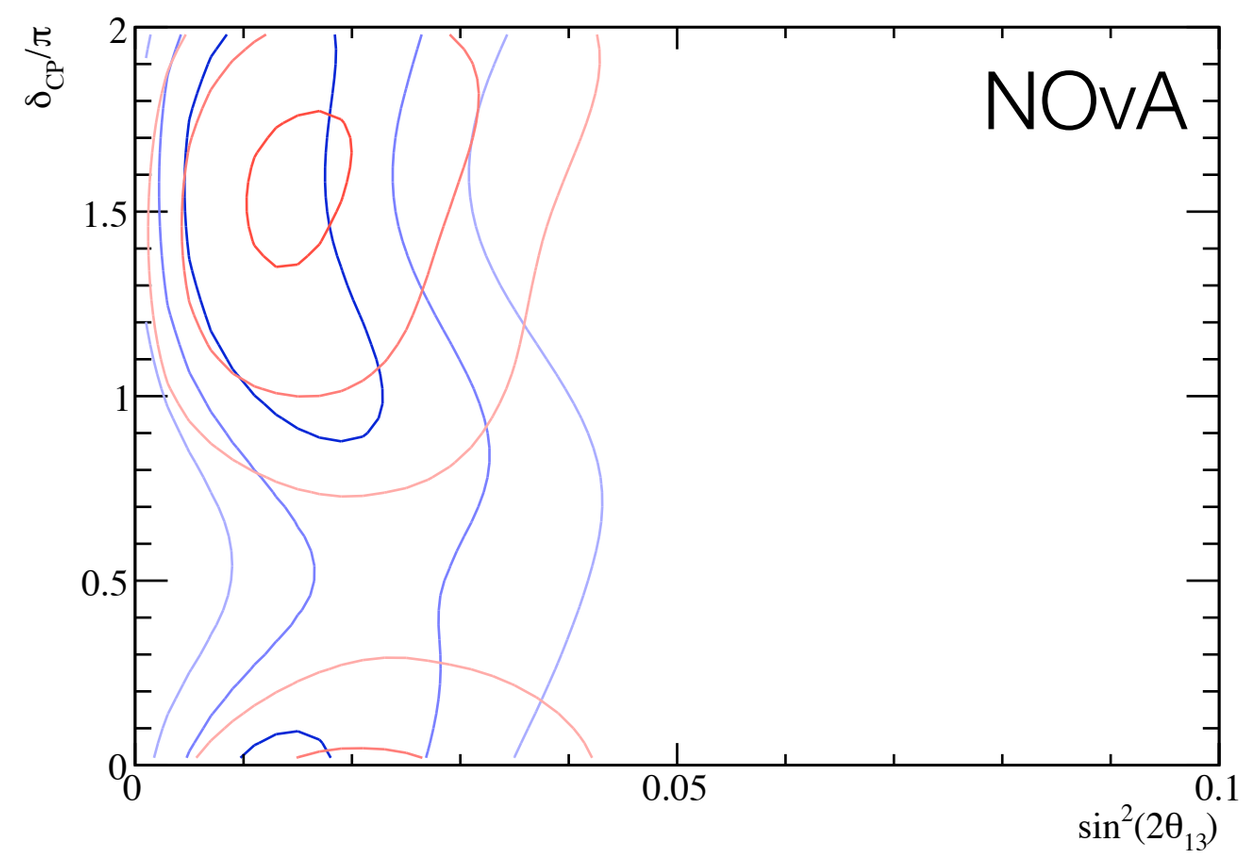

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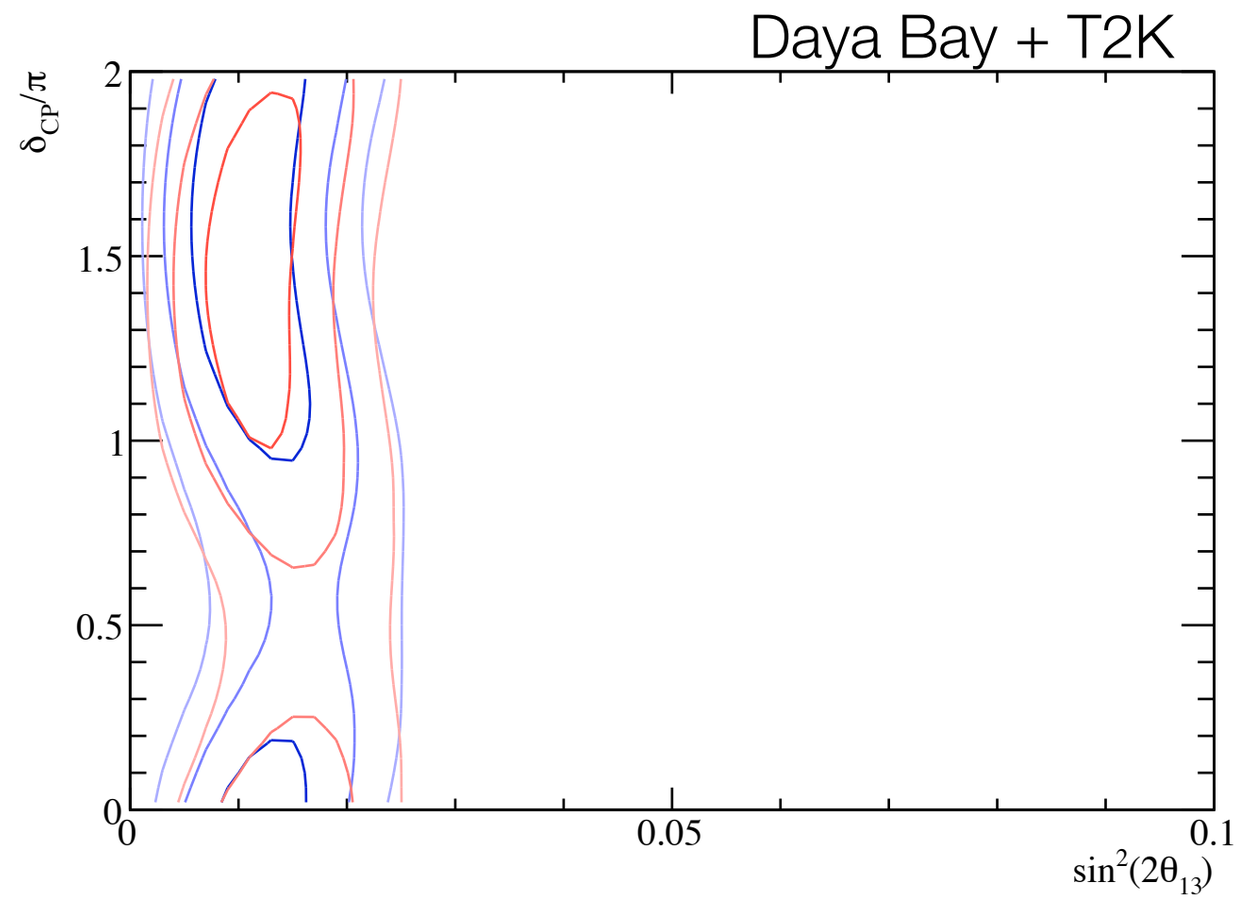

<u>*Daya Bay + T2K*</u>

- T2K helps confirm marginal signal from reactor
- No sensitivity to hierarchy
- No sensitivity to CP phase at >3 sigma.
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<u>*Daya Bay + T2K + NOvA*</u>

- Inverted hierarchy disfavored at 1 sigma
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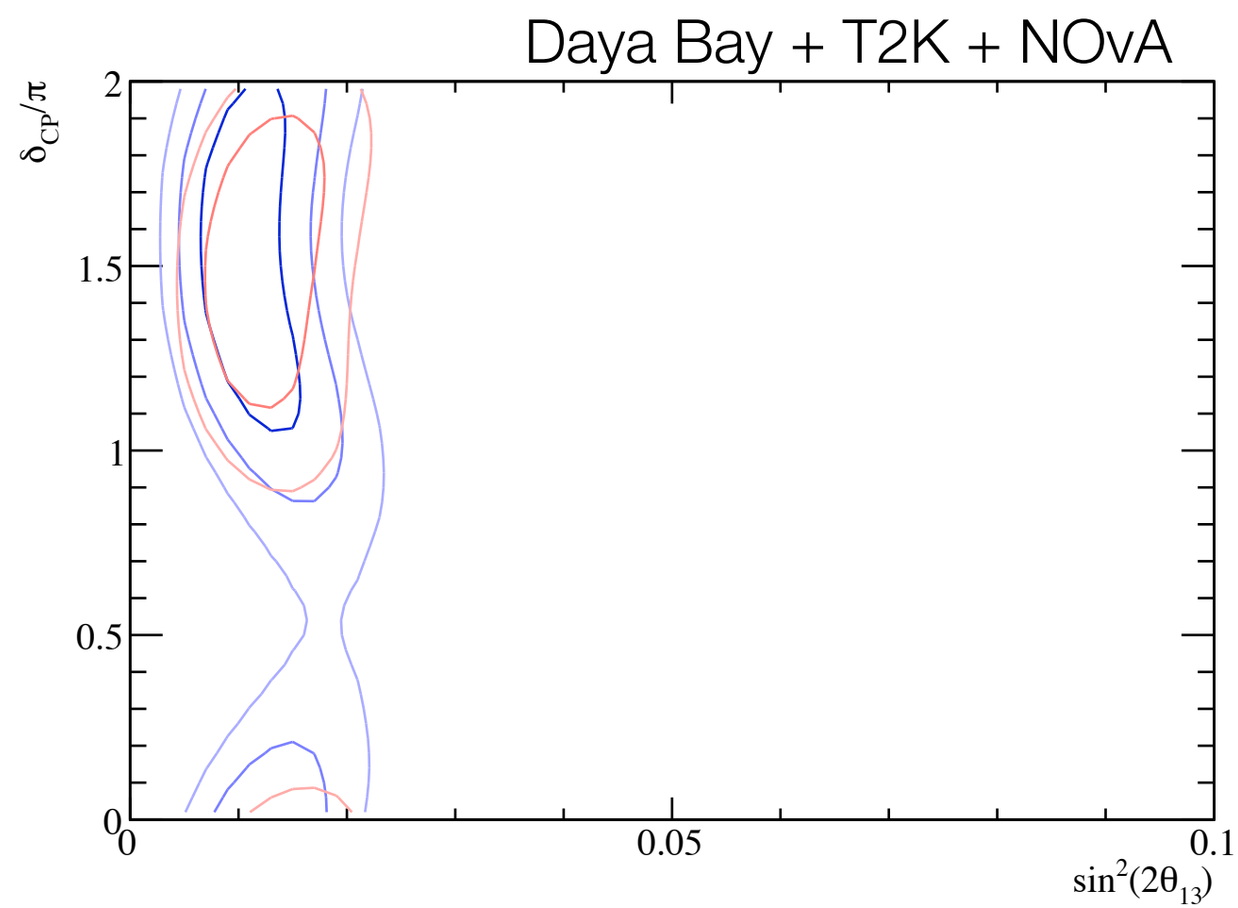
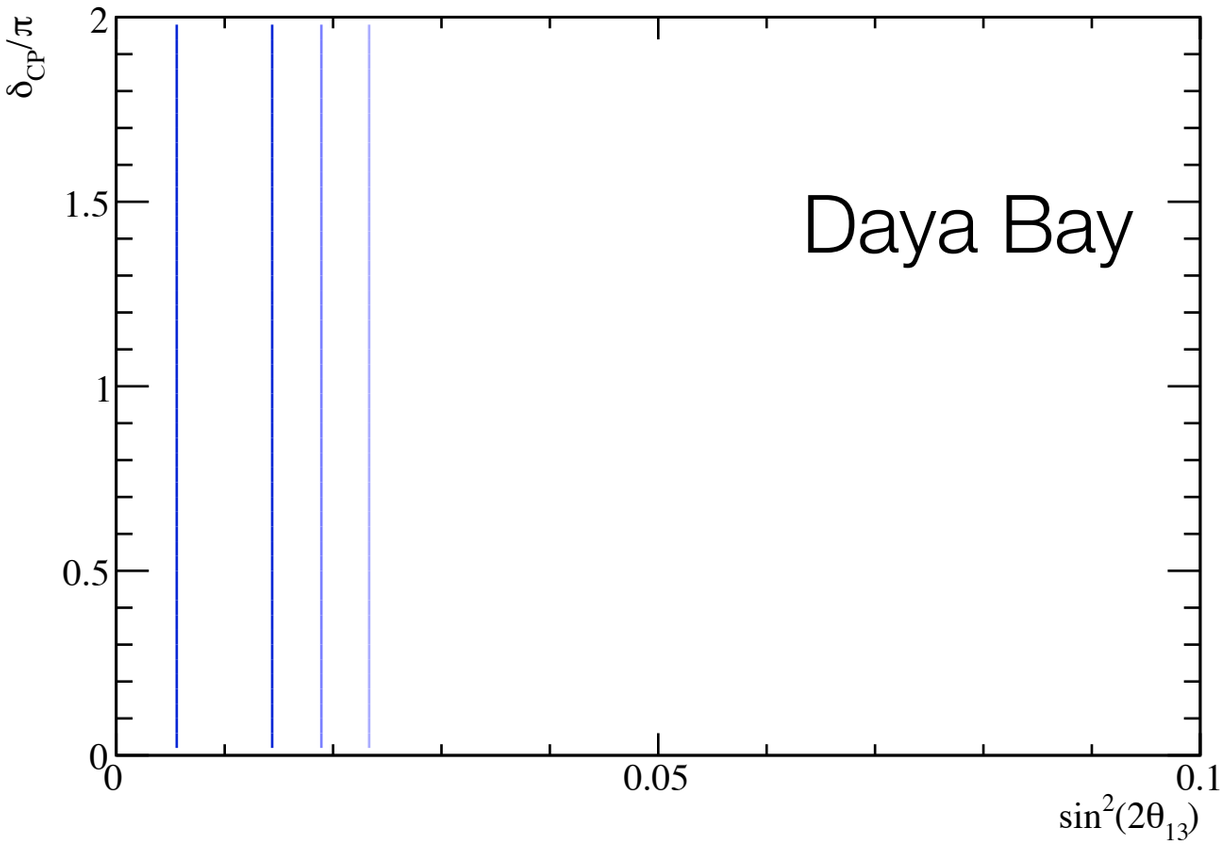
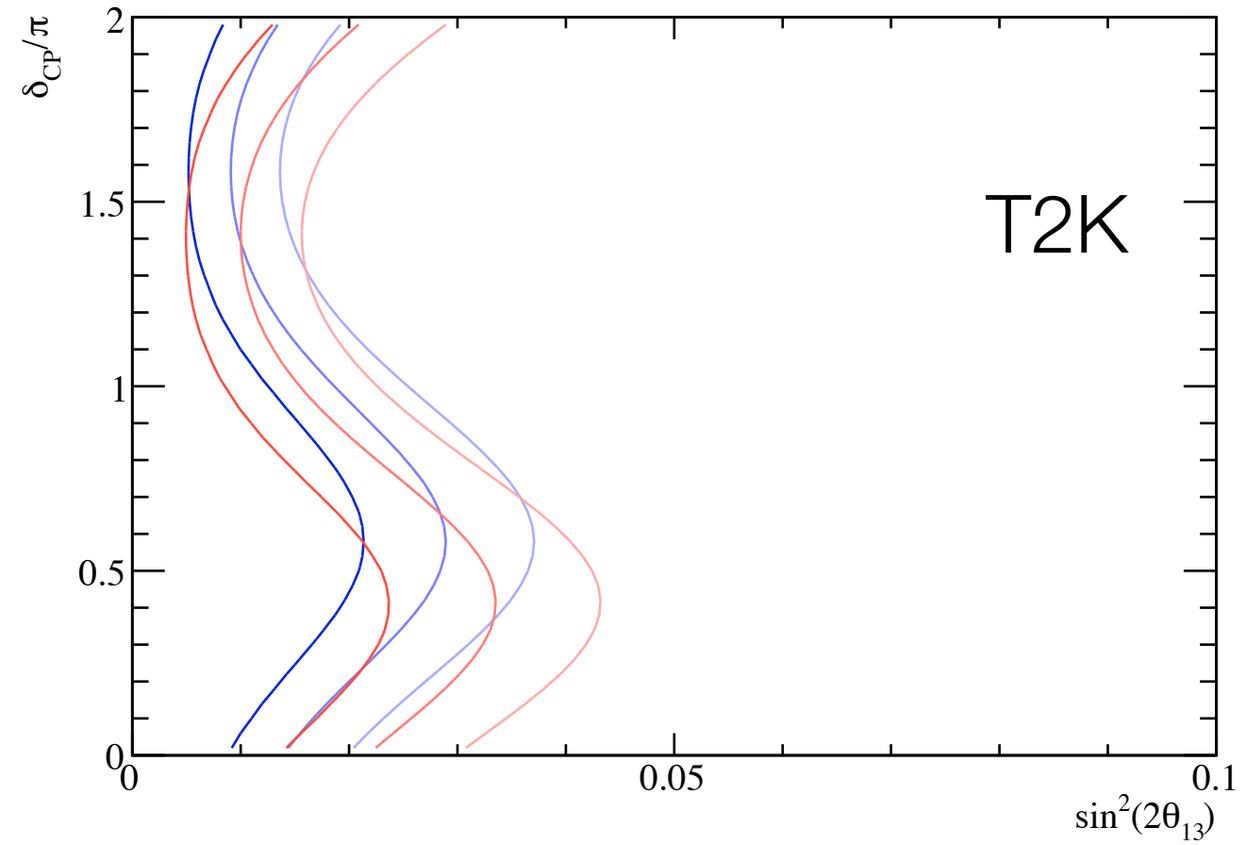
- $0.2 < \delta/\pi < 0.9$ disfavored at 2 sigma (35% of space)







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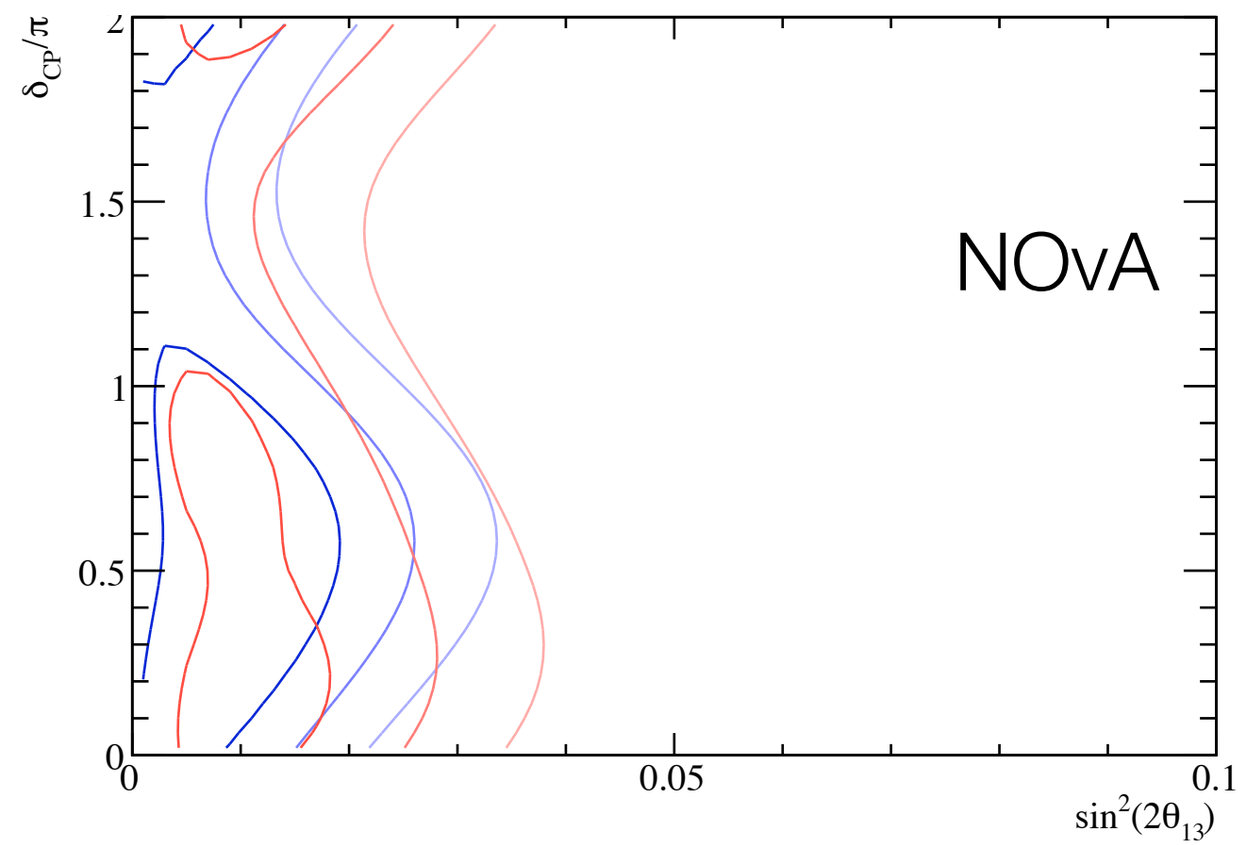

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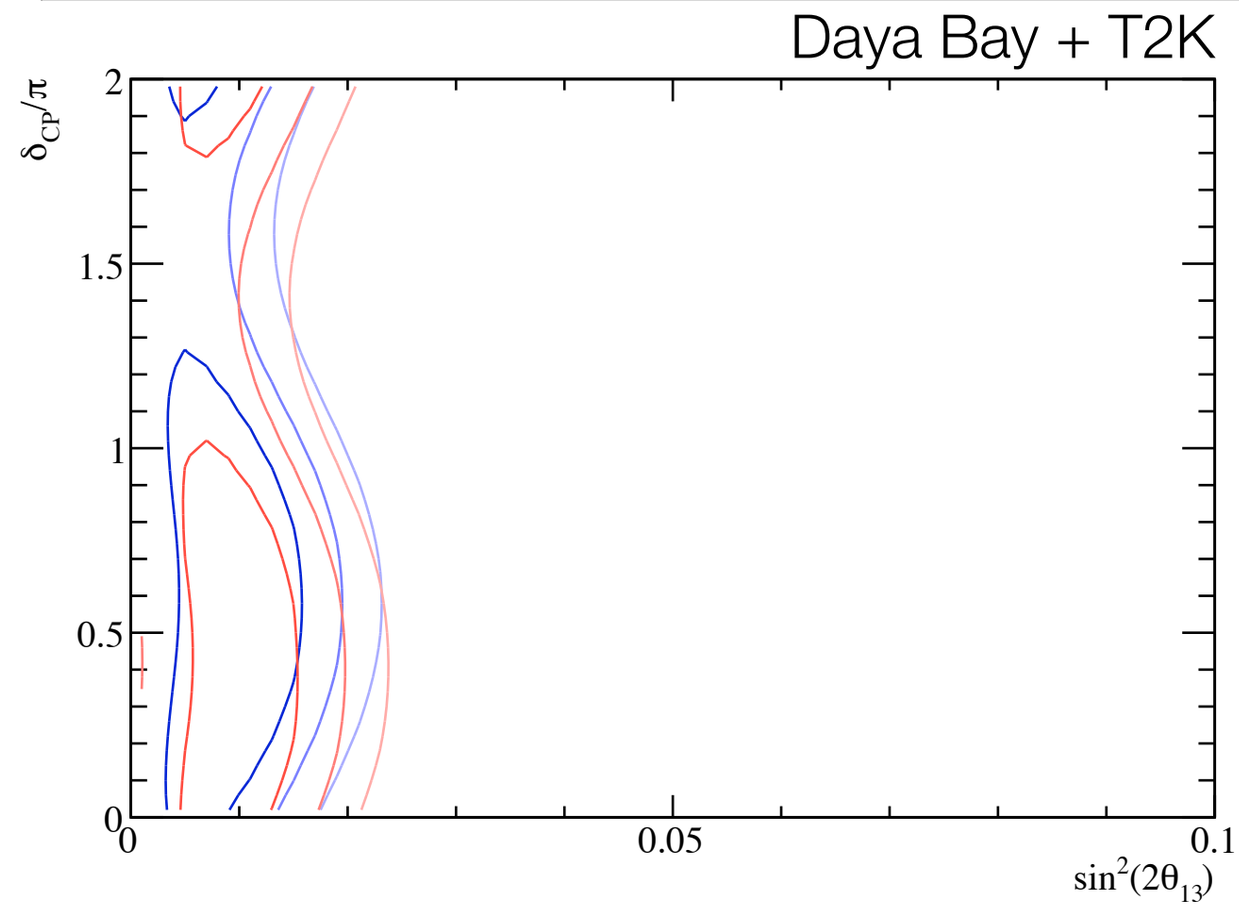

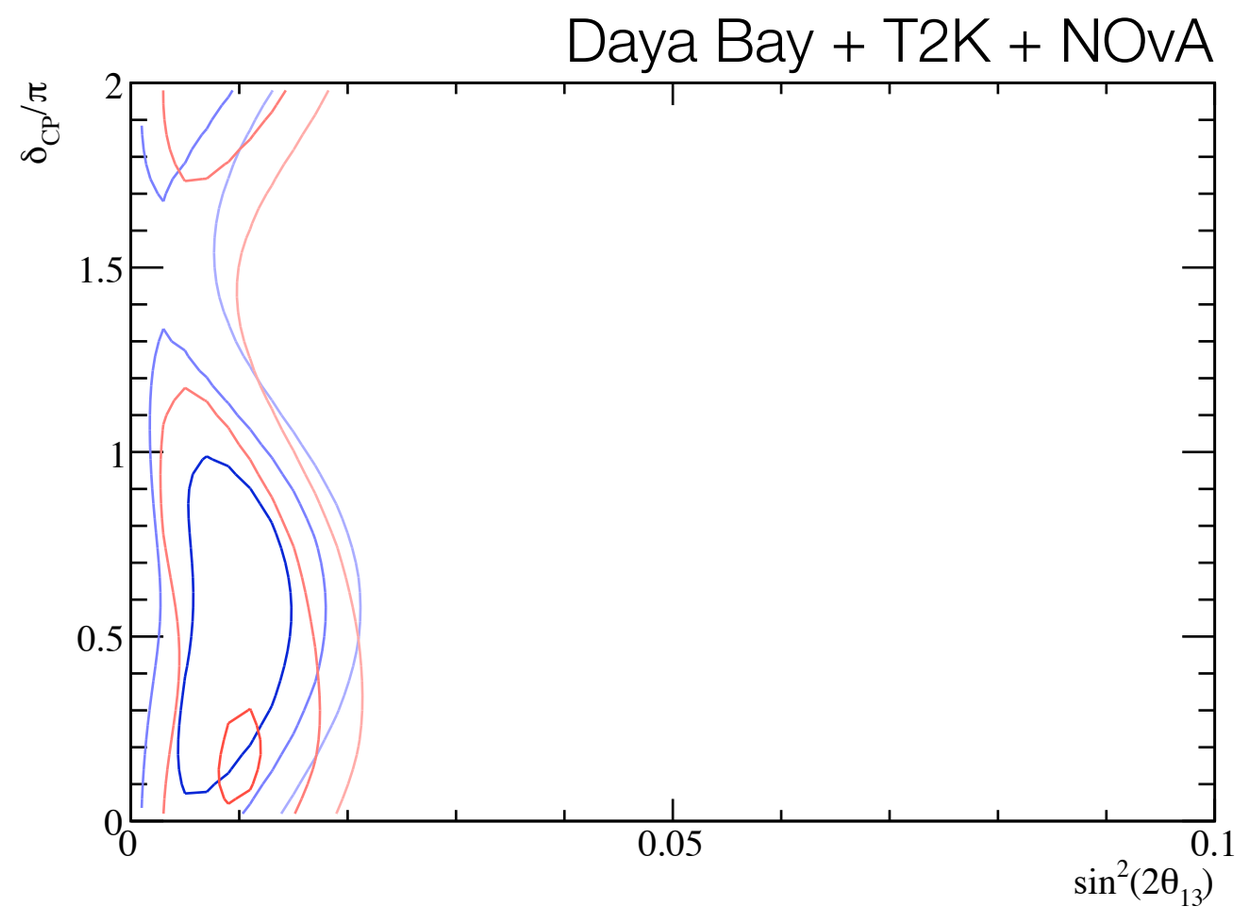

Daya Bay + T2K

- T2K fails to confirm marginal signal from reactor
- No sensitivity to hierarchy
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Daya Bay + T2K + NOvA

- Small region for inverted hierarchy allowed at 1 sigma
- No sensitivity to CP phase at >3 sigma
- $1.4 < \delta/\pi < 1.7$ disfavored at 2 sigma (15% of space)