

Sensitivity To Mass Hierarchy Without ND-LAr Spectral Information

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ND Alternatives Analysis

Tuesday, March 8, 2022

Premise

- Without ND-LAr, neutrino energy spectra at the Far Detector cannot be predicted without introducing additional systematics, which we will likely underestimate if we attempt to generate with Monte Carlo.
- One way to avoid introducing extra systematics is to just use the Far Detector as a *counting experiment* and perform a fit with only one bin in energy.
- This is a very conservative approach, meant to be considered a lower bound compared to other ND alternative analyses.

Technique

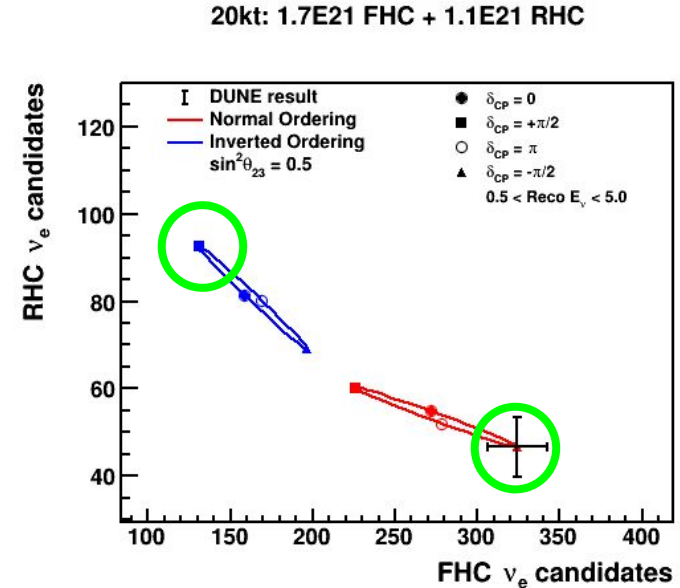
Assumed Run Plan

Total POT / Year / Operation Mode	Year 1	Year 2	Year 3	Year 4
FHC	5E20	10E20	17E20	17E20
RHC	0	0	0	11E20

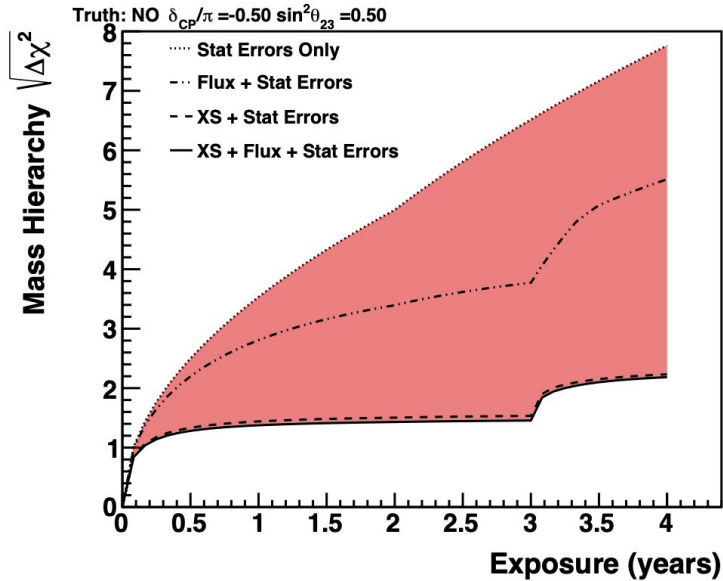
- For an ensemble of truth scenarios (NO, IO; $\delta_{CP} = 0, \pm\pi/2$; $\sin^2(\theta_{23}) = 0.5$):
 - Integrate reconstructed FD spectra from 1-5 GeV (full spectra in backup)
 - Use FHC ν_e and RHC ν_e event counts to find best-fit wrong order scenario
- Use varying levels of uncertainty as a proxy for different ND alternatives without ND-LAR
 - **Statistical only**- Perfect flux constraint, perfect constraint of total XS on Ar
 - **Stat + full flux uncertainties**- No flux constraint, perfect a priori knowledge of total XS on Ar
 - **Stat + XS uncertainty (A-Scaling)**- Perfect flux constraint, perfect XS constraint on C
 - **Stat + flux + XS uncertainties**- No flux constraint, XS constraint on C

Results

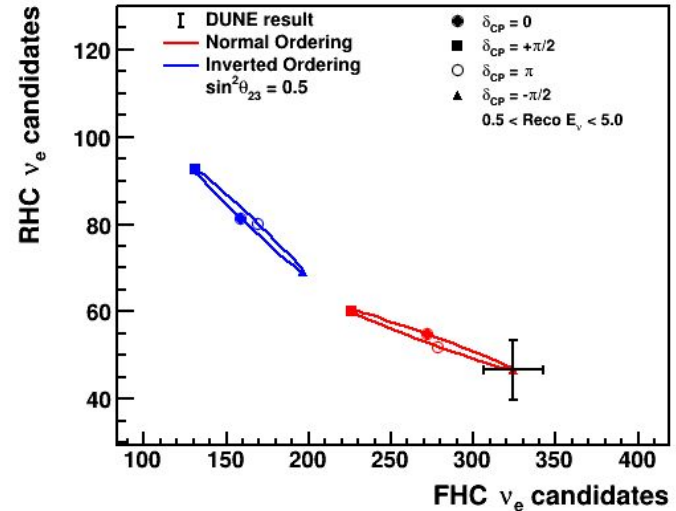
- When the effects of mass ordering and δ_{CP} work in the same direction AND when excluding A-scaling uncertainty, conclude a $>5\sigma$ sensitivity.



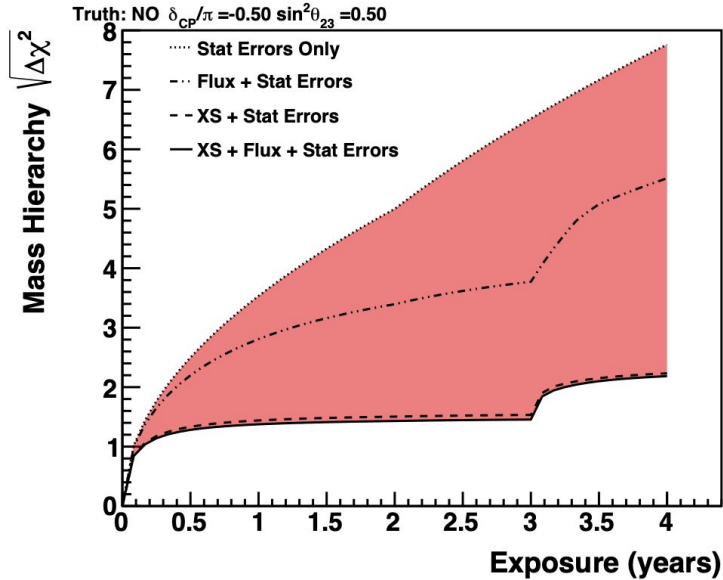
Normal Ordering, $\delta_{CP} = -\pi/2$



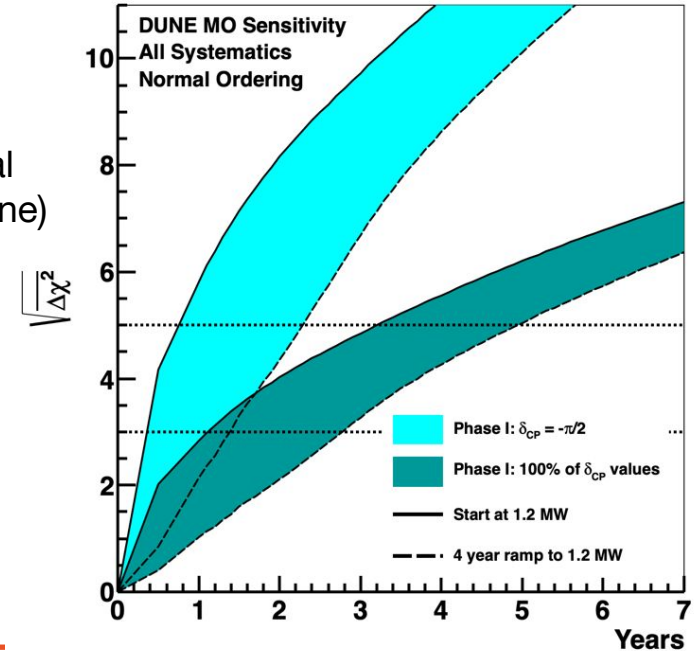
20kt: 1.7E21 FHC + 1.1E21 RHC



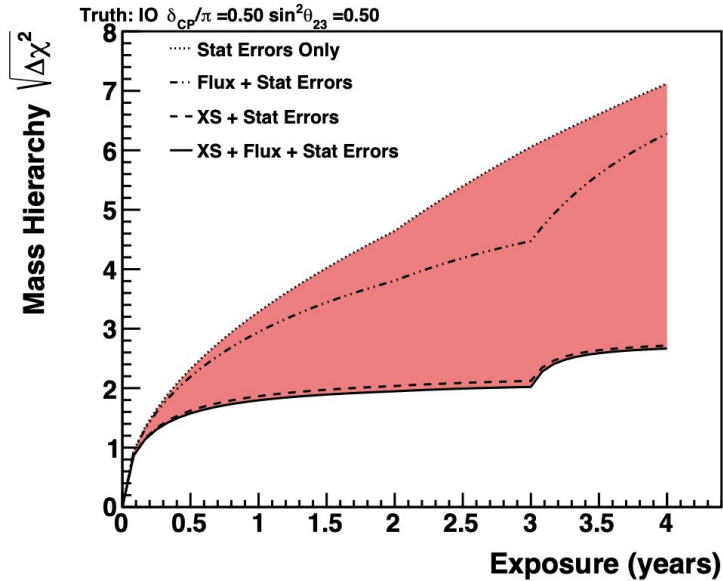
Normal Ordering, $\delta_{CP} = -\pi/2$



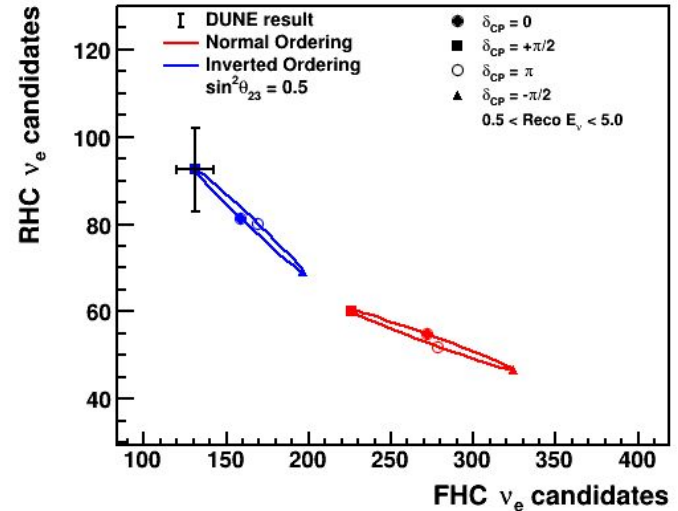
Compare to full systematics nominal (light blue dashed line)



Inverted Ordering, $\delta_{CP} = \pi/2$

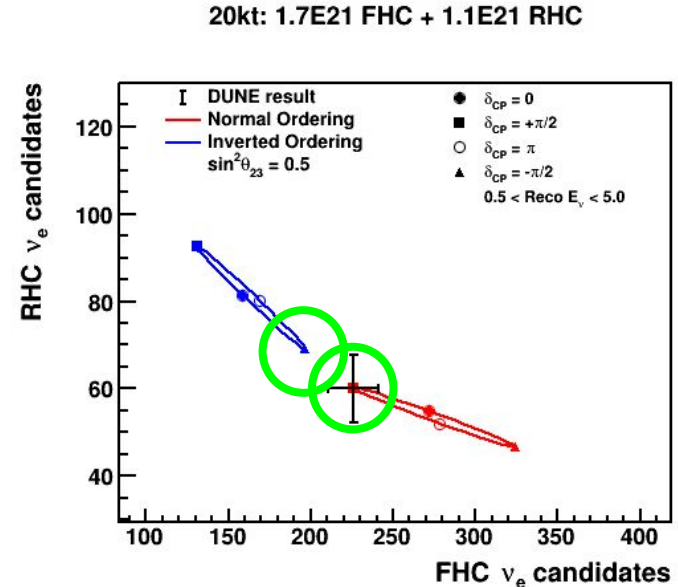


20kt: 1.7E21 FHC + 1.1E21 RHC

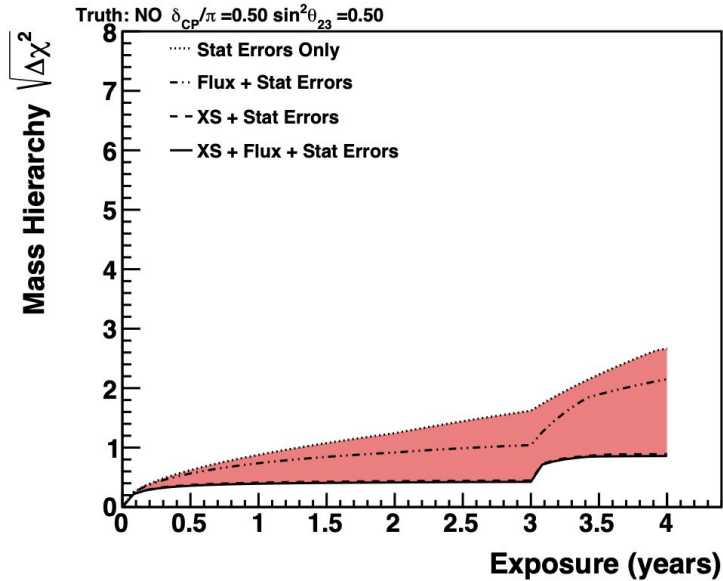


Results

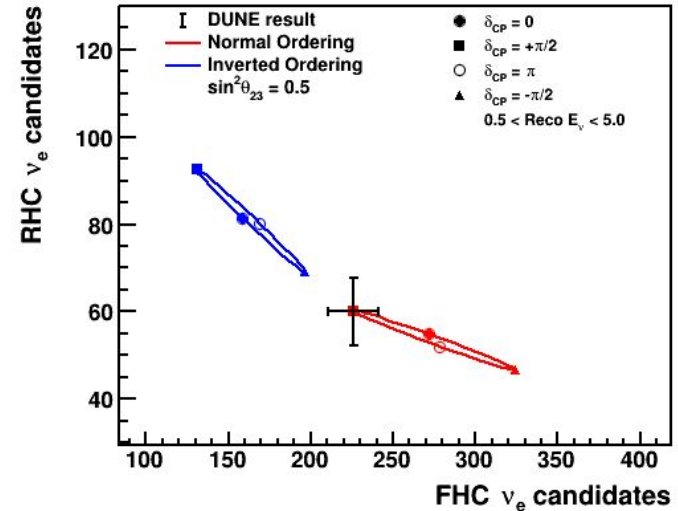
- When the effects of mass ordering and δ_{CP} work in the same direction AND when excluding A-scaling uncertainty, conclude a $>5\sigma$ sensitivity.
- When they act oppositely, even the most idealized case drops to $\sim 2\sigma$.



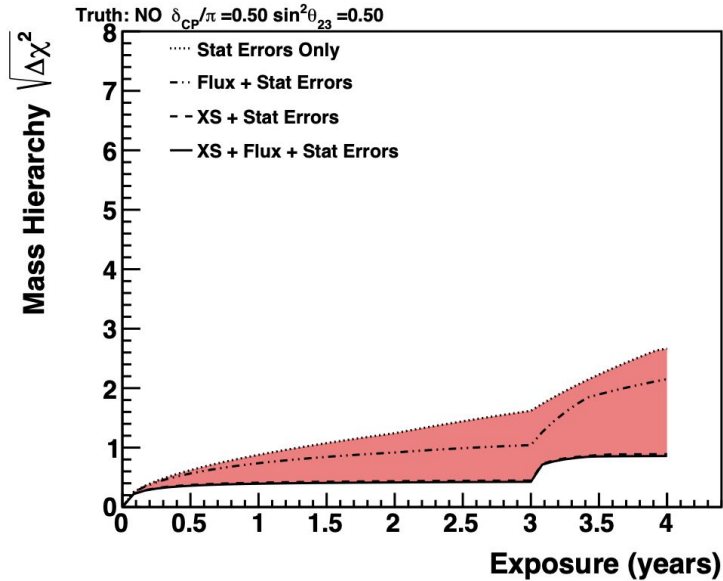
Normal Ordering, $\delta_{CP} = \pi/2$



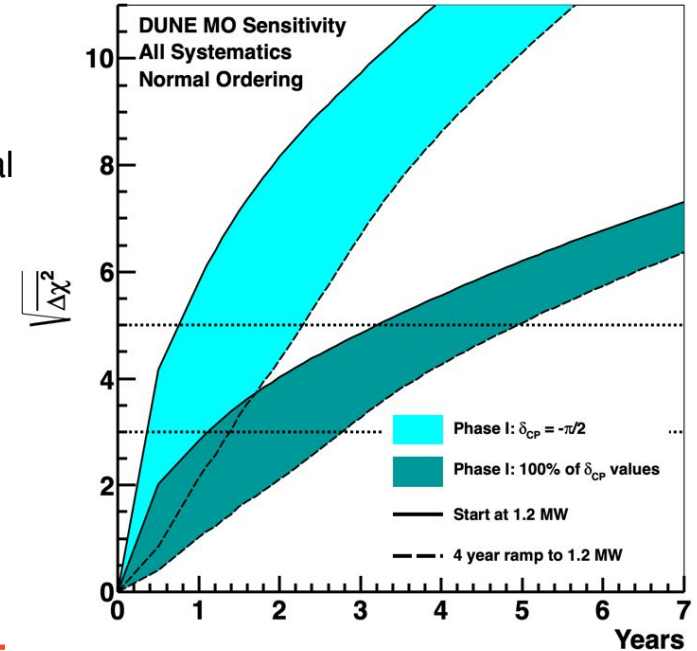
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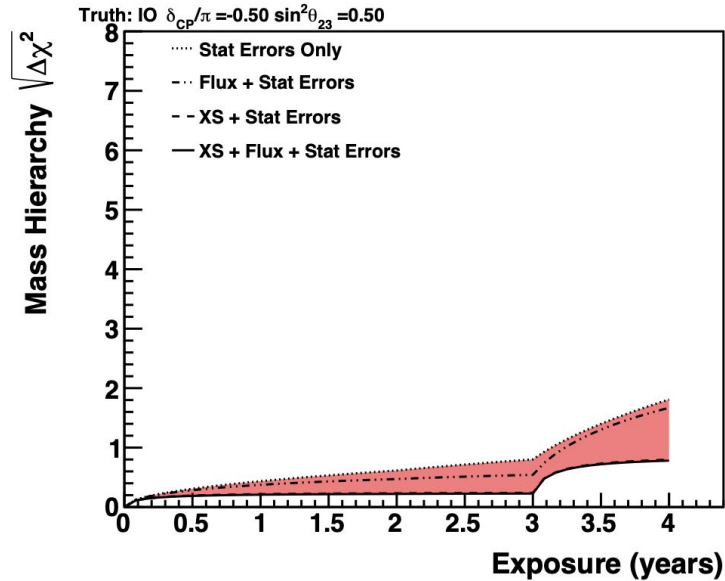
Normal Ordering, $\delta_{CP} = \pi/2$



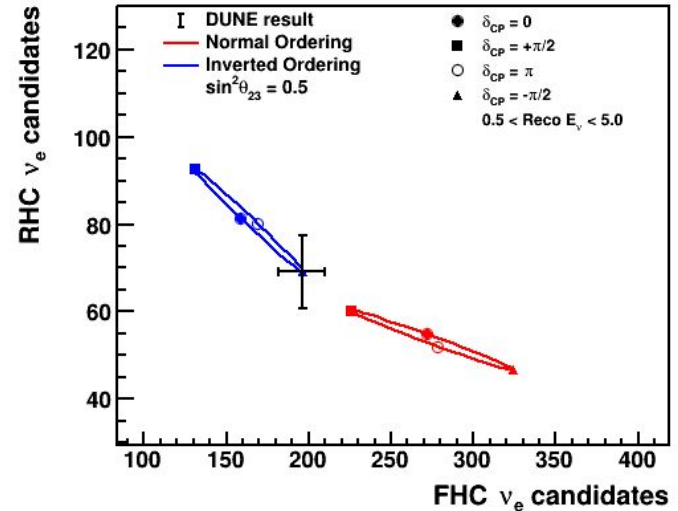
Compare to full systematics nominal (dark green dashed line)



Inverted Ordering, $\delta_{CP} = -\pi/2$

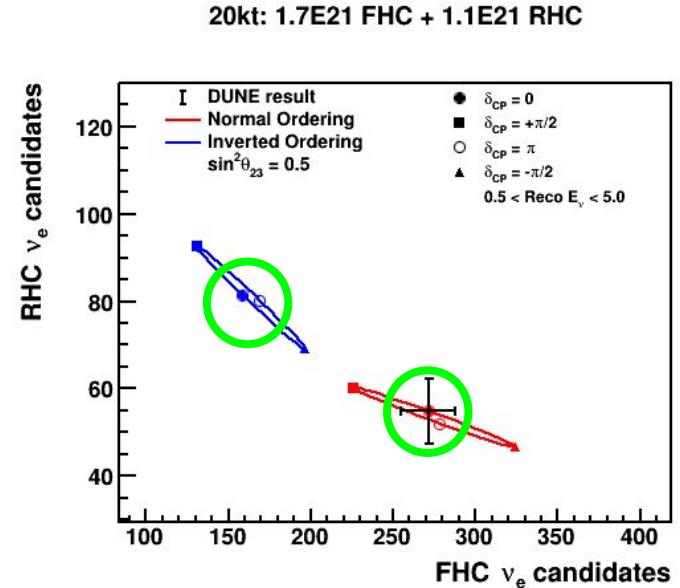


20kt: 1.7E21 FHC + 1.1E21 RHC

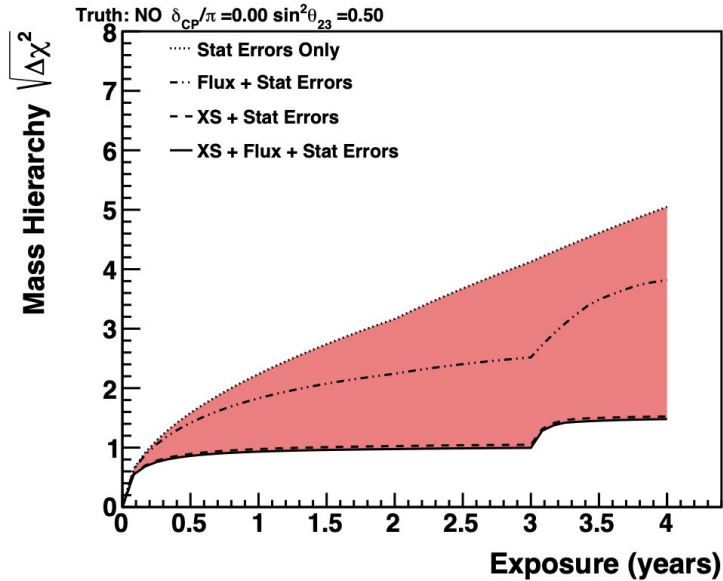


Results

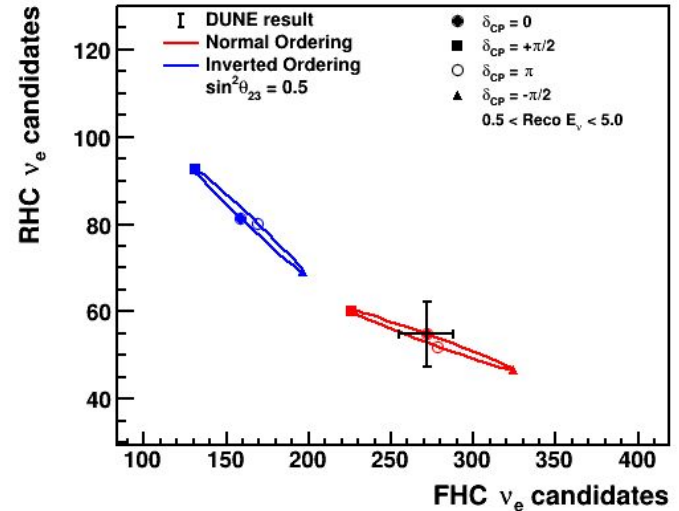
- When the effects of mass ordering and δ_{CP} work in the same direction AND when excluding A-scaling uncertainty, conclude a $>5\sigma$ sensitivity.
- When they act oppositely, even the most idealized case drops to $\sim 2\sigma$.
- In the middle, we see sensitivities in the middle, still dominated by the cross section uncertainties.



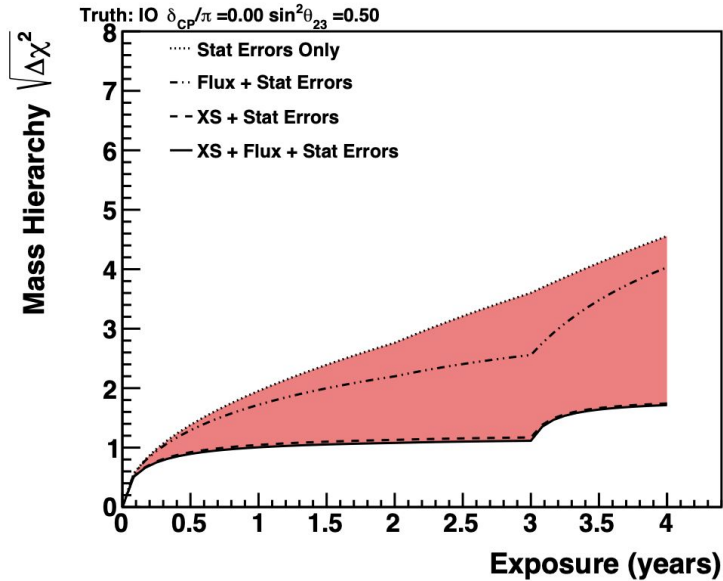
Normal Ordering, $\delta_{CP} = 0$



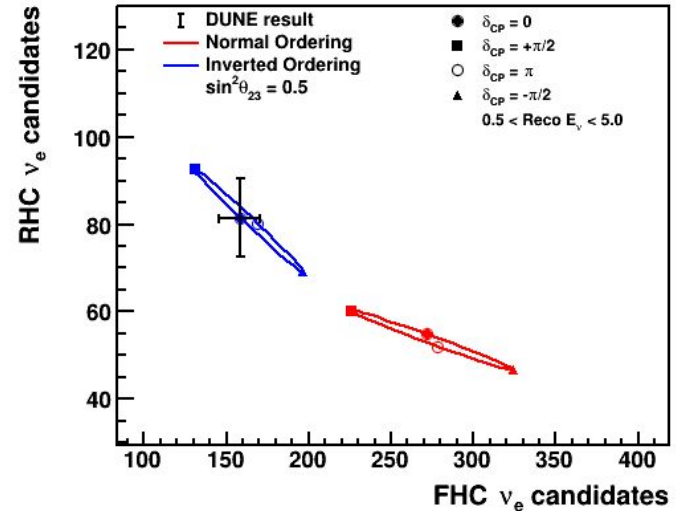
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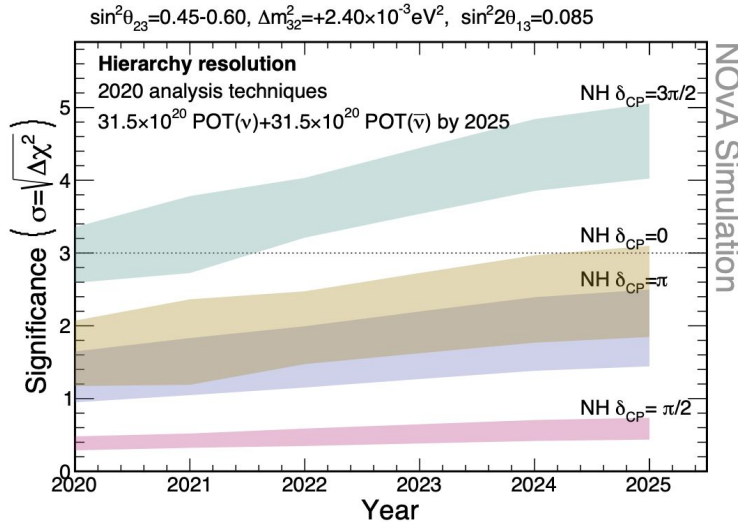
Inverted Ordering, $\delta_{CP}=0$



20kt: 1.7E21 FHC + 1.1E21 RHC



Conclusions

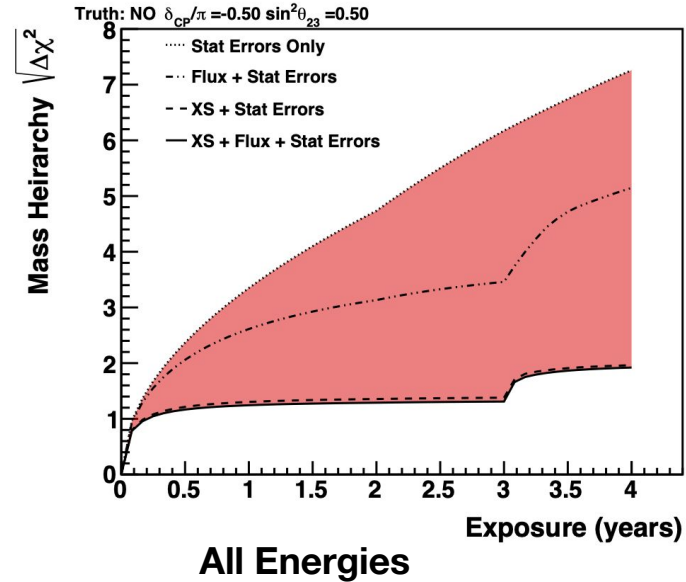
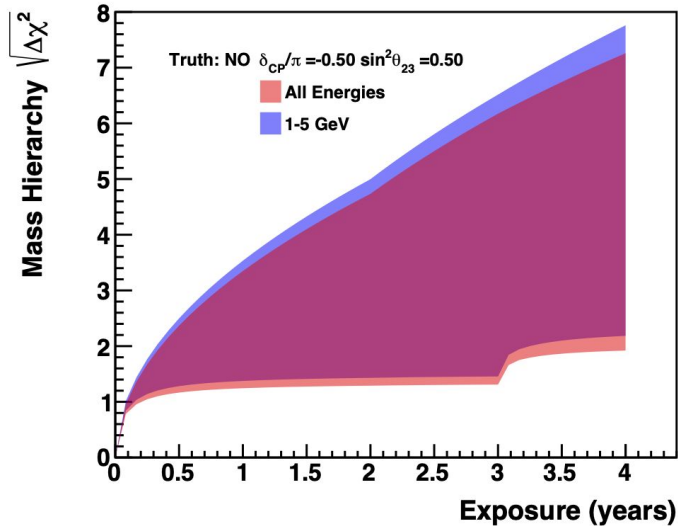


- The idealized mass ordering resolution without any systematics is highly conditional and on par with that of $\text{NO}\nu\text{A}$.
- The inclusion of cross section systematics dramatically reduces sensitivity, regardless of truth scenario.
- Spectral information from ND-LAr will be crucial for an early measurement of the mass ordering.

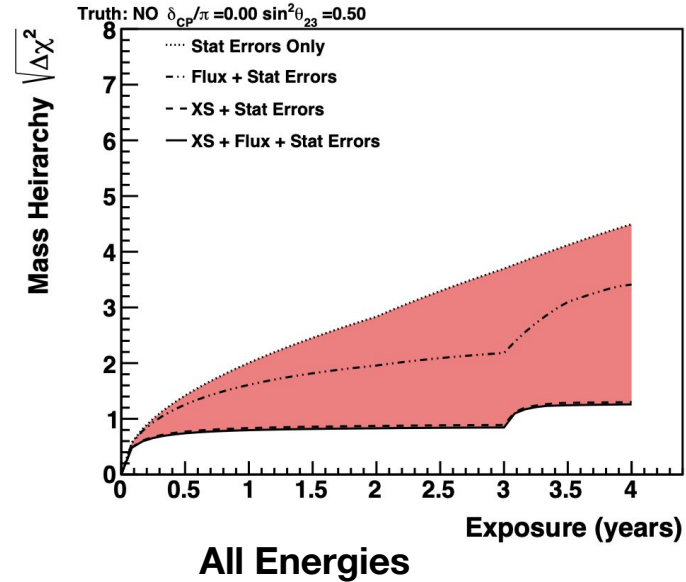
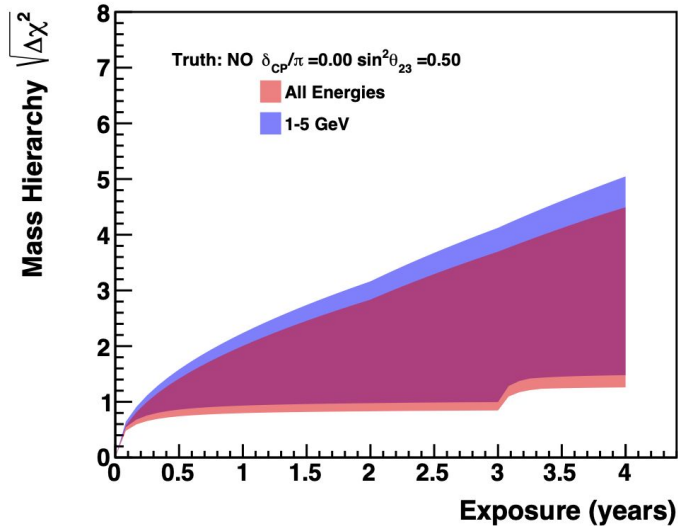
Backups

1-5 GeV vs. All Energies

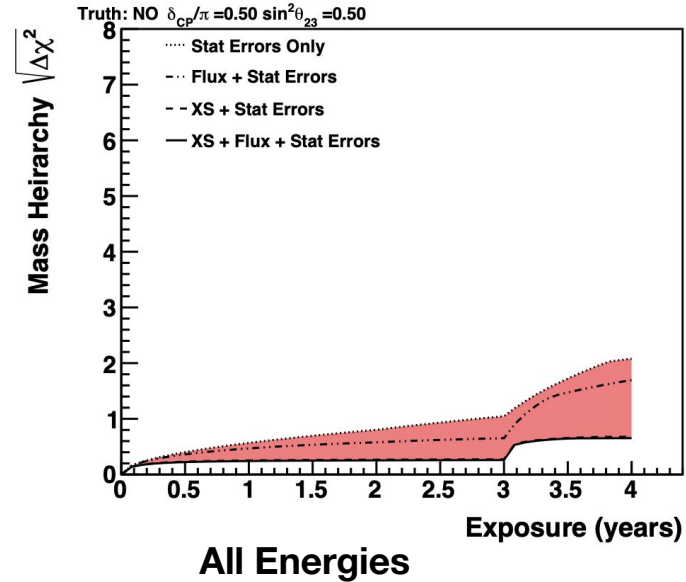
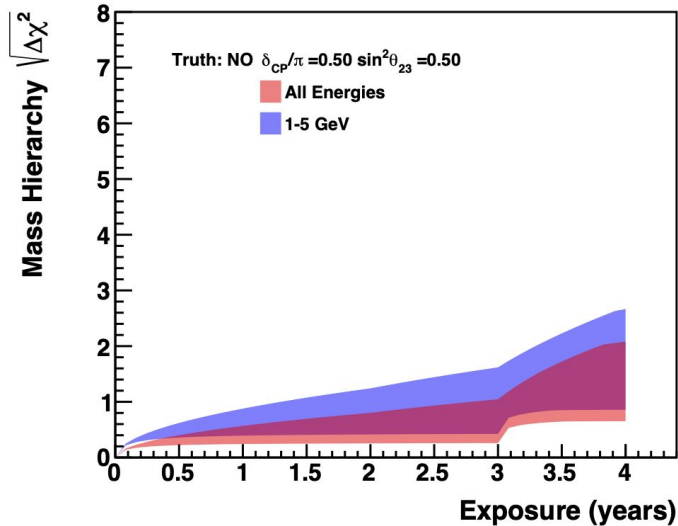
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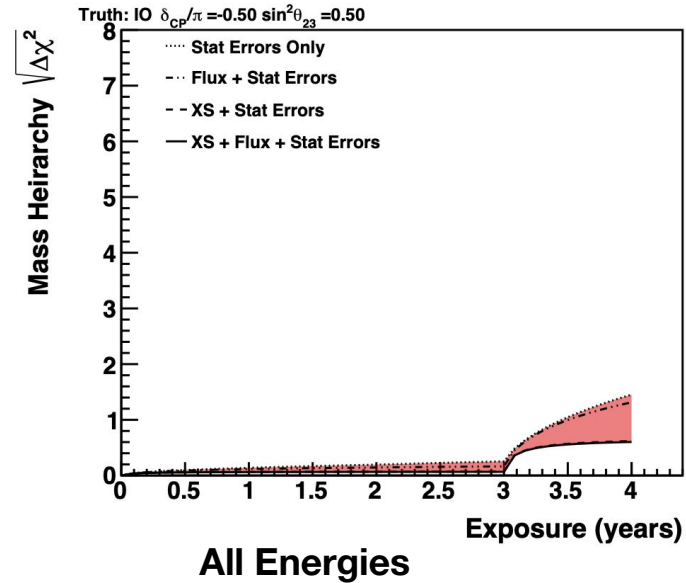
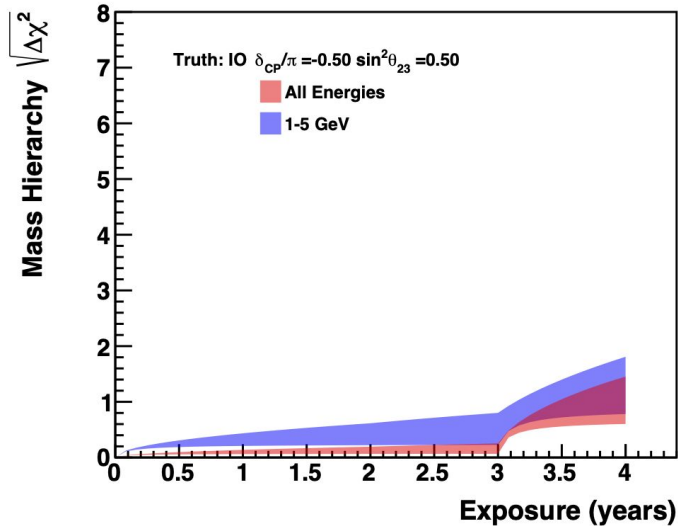
Normal Ordering, $\delta_{CP} = 0$



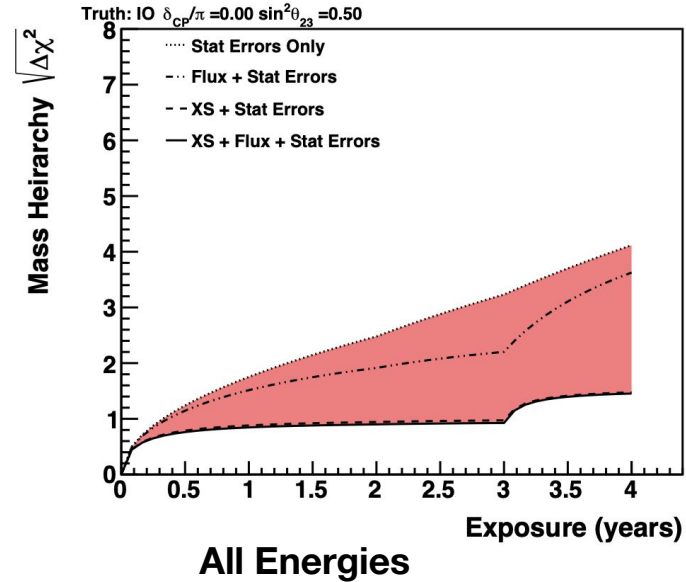
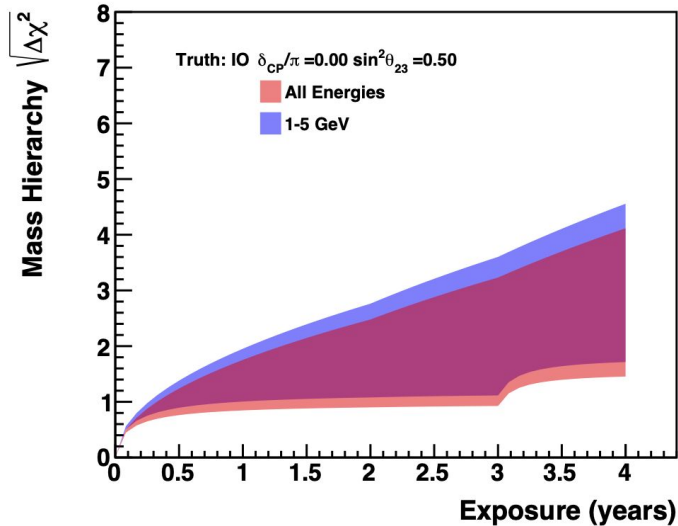
Normal Ordering, $\delta_{CP} = \pi/2$



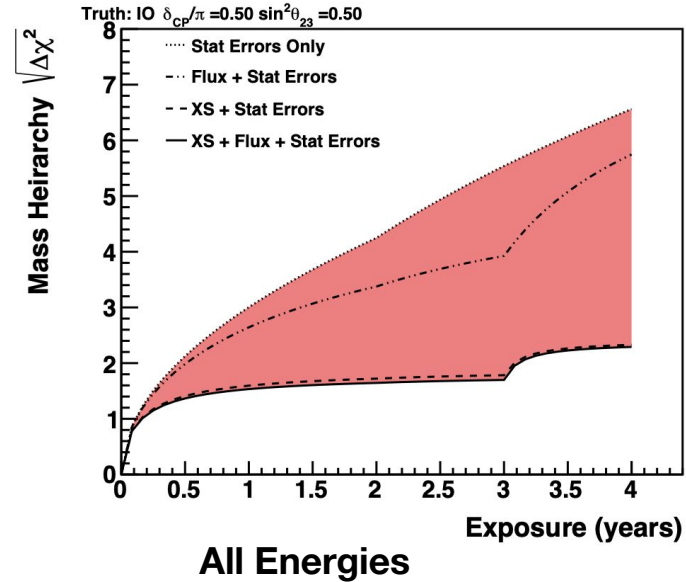
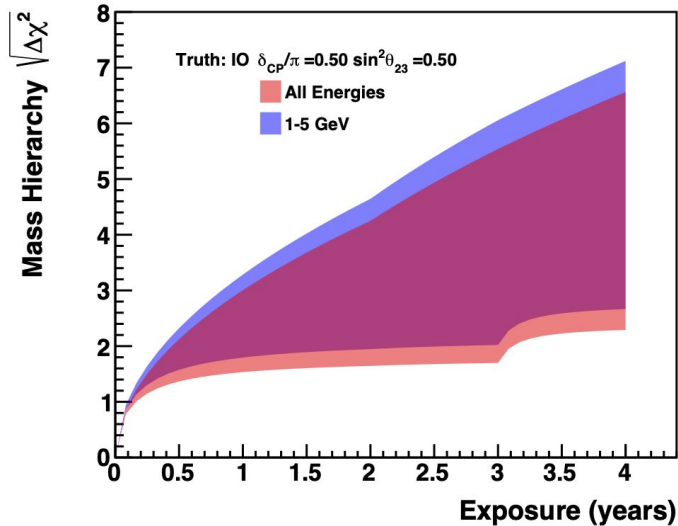
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Inverted Ordering, $\delta_{CP} = 0$



Inverted Ordering, $\delta_{CP} = \pi/2$

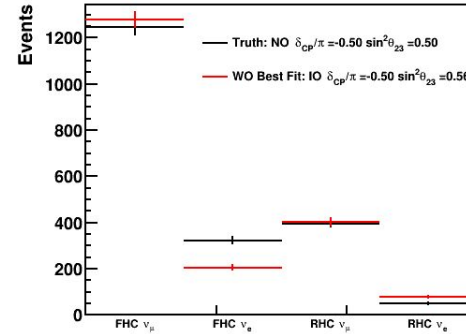
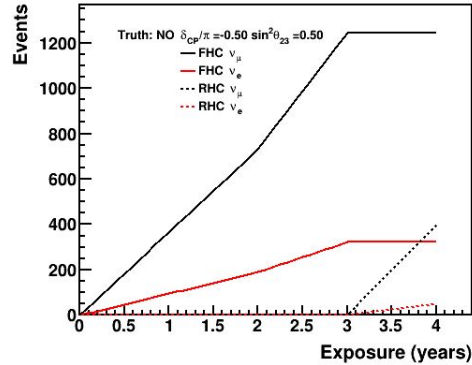


Stats

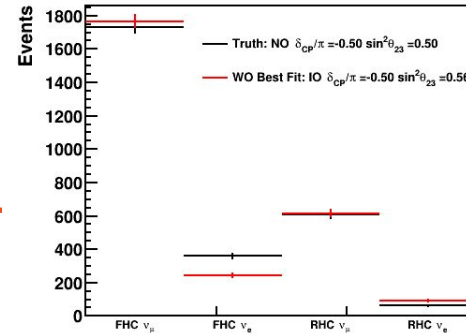
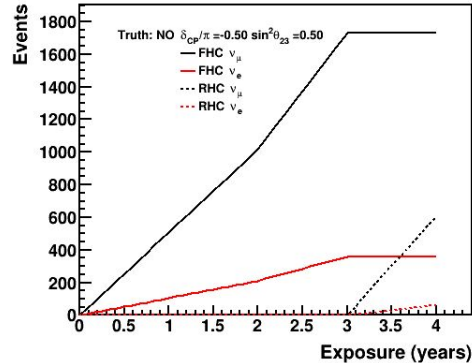


Normal Ordering, $\delta_{CP} = -\pi/2$

1-5 GeV

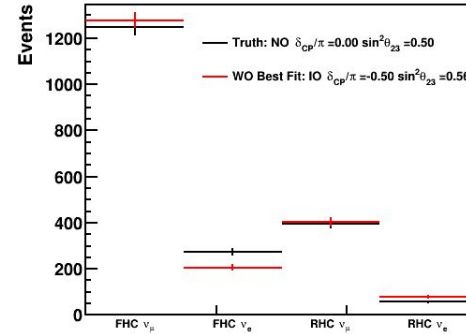
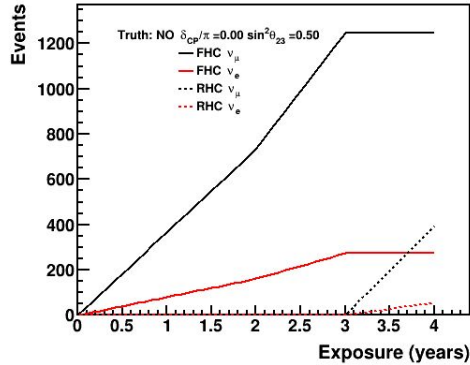


All Energies

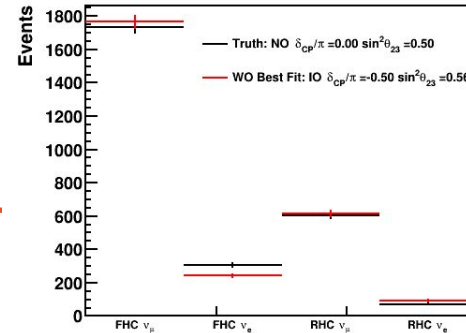
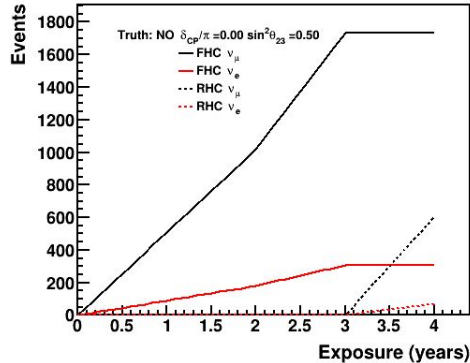


Normal Ordering, $\delta_{CP} = 0$

1-5 GeV

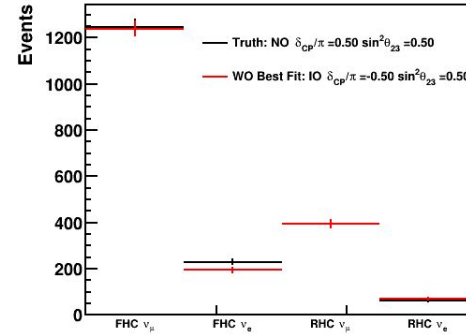
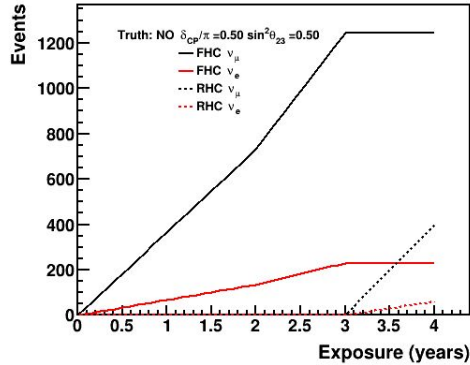


All Energies

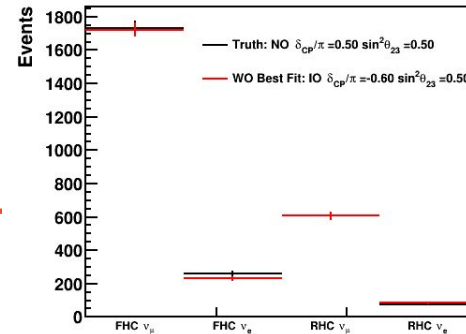
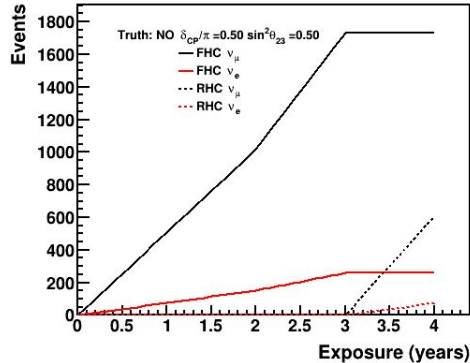


Normal Ordering, $\delta_{CP} = \pi/2$

1-5 GeV

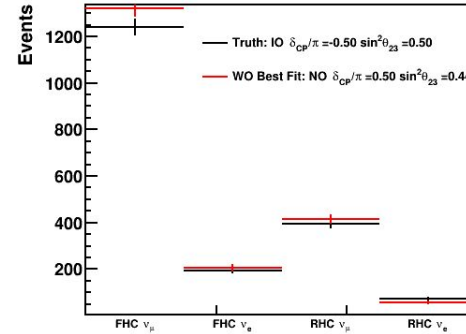
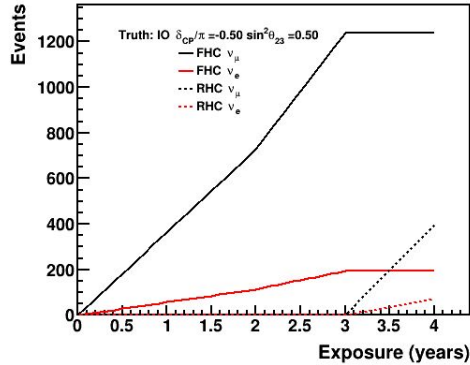


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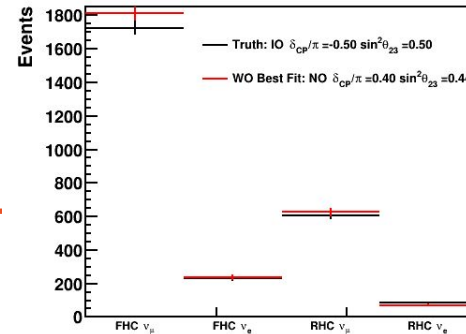
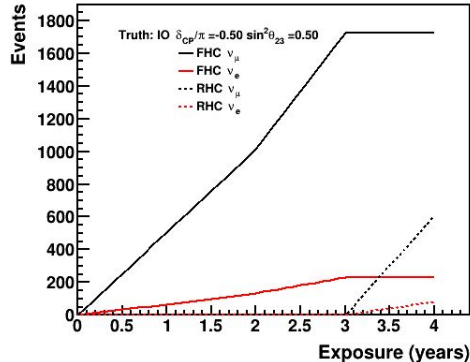


Inverted Ordering, $\delta_{CP} = -\pi/2$

1-5 GeV

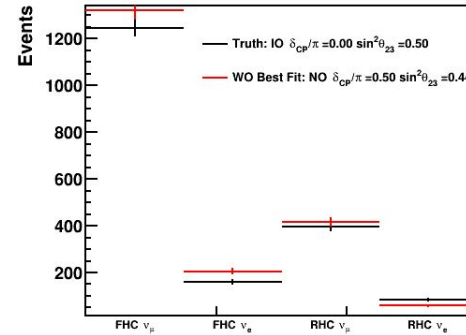
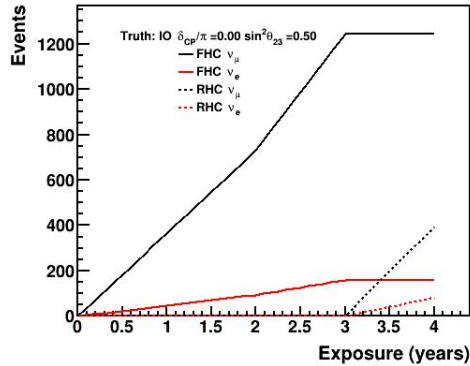


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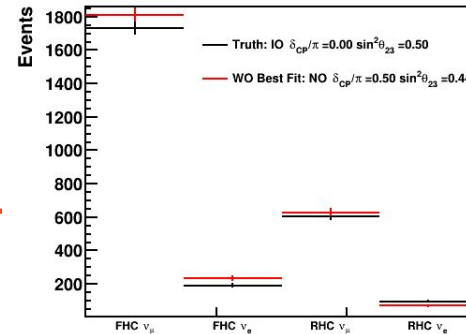
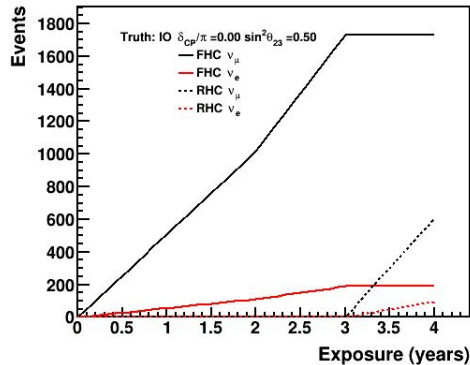


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1-5 GeV

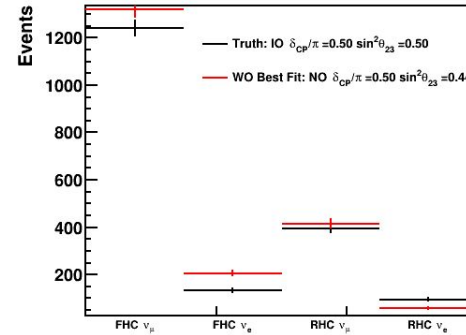
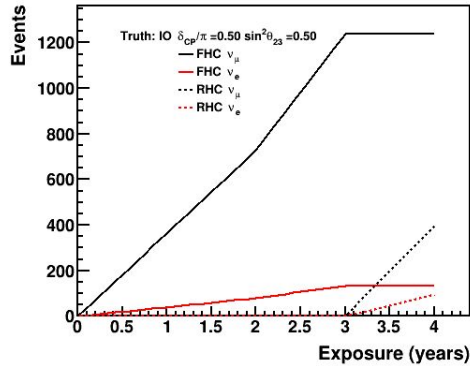


All Energies



Inverted Ordering, $\delta_{CP} = \pi/2$

1-5 GeV



All Energies

