INSS 2019
Group Work Presentation

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Section 4: Long Baseline Oscillation Experiments
Problem 1

1. Given the following sets of oscillation parameters, what would be the optimal run plan for NOvA to determine specifically the mass hierarchy ? Assume $36 \times 10^{20}\ POT$ and monochromatic beam at $E = 1.9\ GeV$.

   1. $NH,\ sin^2(\theta_{23}) = 0.6,\ \delta_{cp} = \frac{3\pi}{2}$
   2. $NH,\ sin^2(\theta_{23}) = 0.4,\ \delta_{cp} = \frac{3\pi}{2}$
   3. $IH,\ sin^2(\theta_{23}) = 0.6,\ \delta_{cp} = \frac{3\pi}{2}$
   4. $IH,\ sin^2(\theta_{23}) = 0.4,\ \delta_{cp} = \frac{\pi}{2}$

2. For the case where we do not know those parameters beforehand, what would the run plan be?

3. For which case the run plan for question #2 would fail?

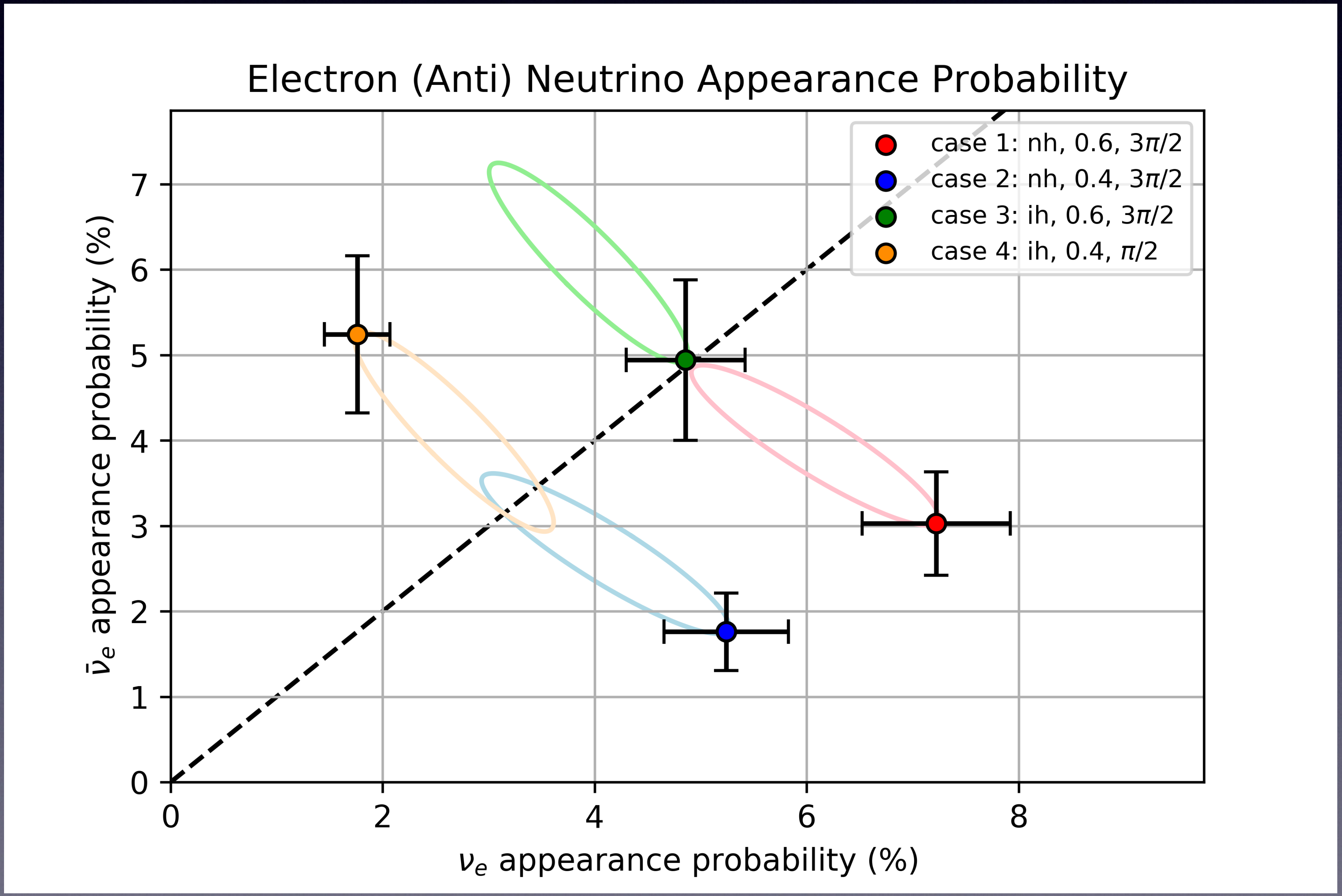
Procedure

- Plot the $P(\nu_\mu \to \nu_e)$ *versus* $P(\bar{\nu}_\mu \to \bar{\nu}_e)$
- Identify the points in it that correspond to the question cases
- Include the error bars
- Project those points in each of the axis
- Look for separation of the peaks (is it better in the neutrino mode or on the antineutrino?)

Methodology

- We are given: $N_{S\ or\ B}^{0.5;\ \nu\ or\ \bar{\nu}}$, for $6 \times 10^{20}\ POT$
- To find the signal count values for $sin^2(\theta_{23}) = 0.4\ or\ 0.6$...
- $$N_S^{0.4} = 6 \times N^{0.5} \times \frac{P(\nu_\mu \to \nu_e)^{0.4}}{P(\nu_\mu \to \nu_e)^{0.5}},$$
- for ν and $\bar{\nu}$, for $\delta_{cp} = \frac{\pi}{2}\ and\ \frac{3\pi}{2}$, for NH and IH

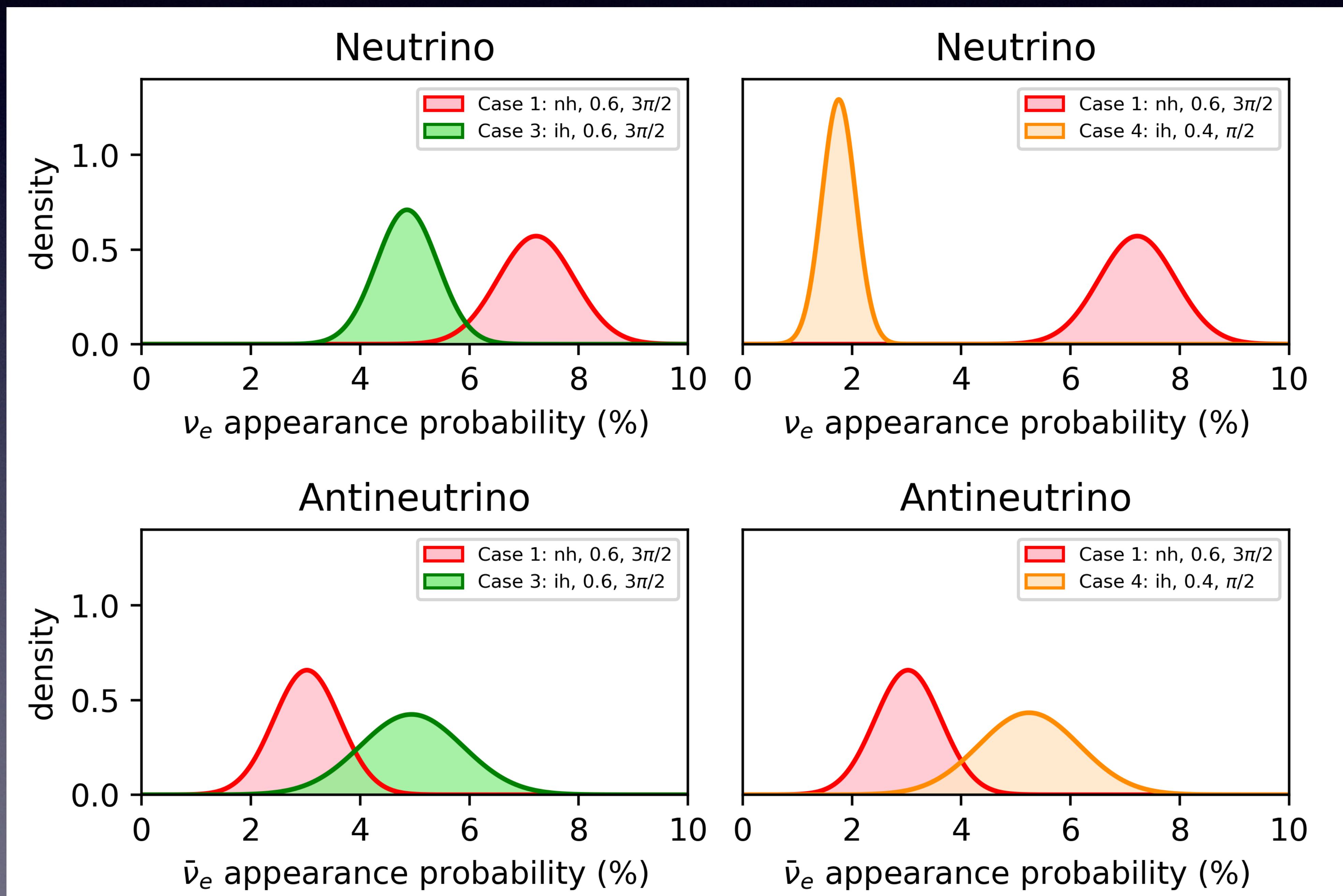
Results - General



Results

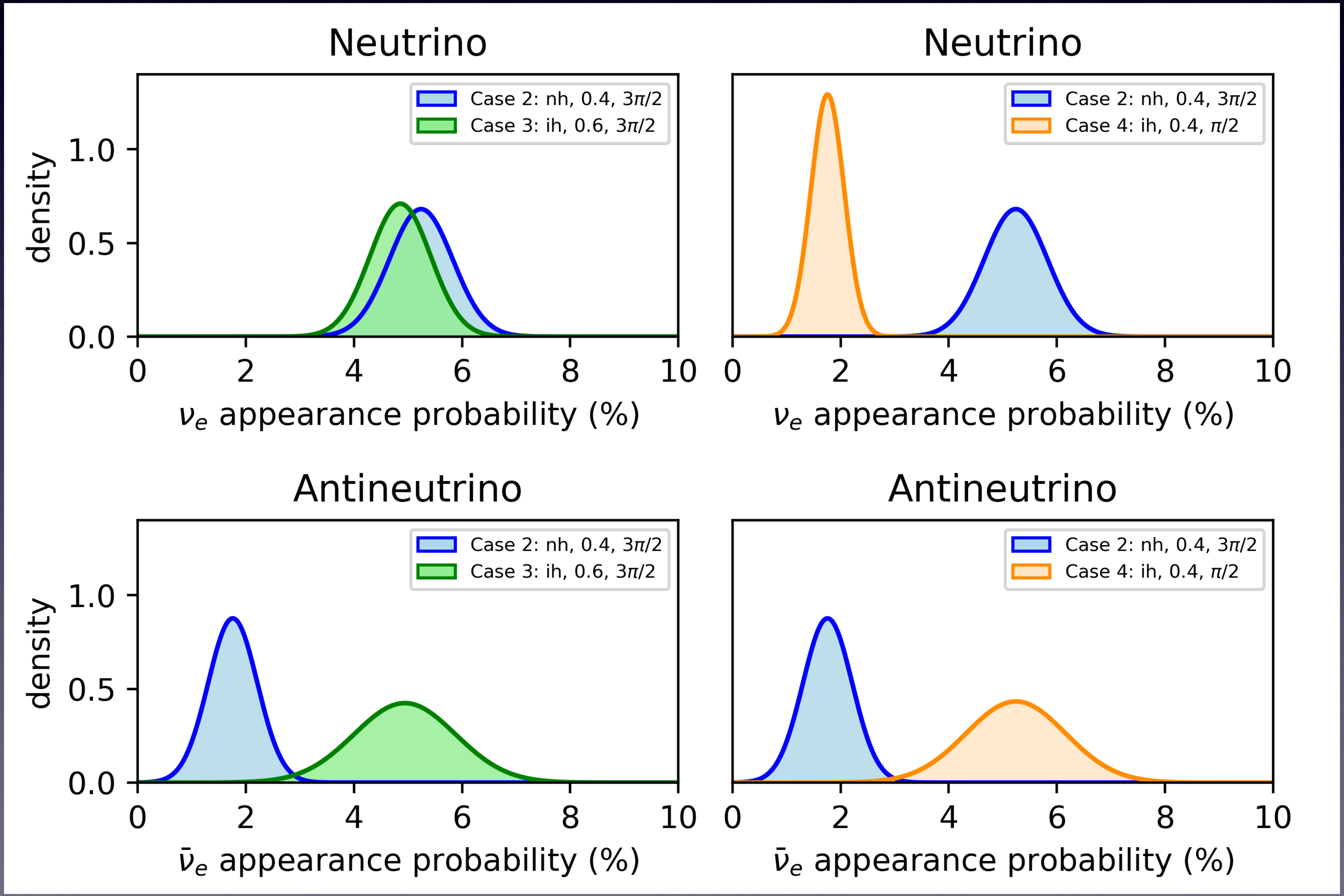
Case 1 and 3

Case 1 and 4



Results

Case 2 and 3 / Case 2 and 4



Conclusion

	Case 3	Case 4
Case 1	Mostly at neutrino	Fully at neutrino
Case 2	Fully at antineutrino	Fully at neutrino

Case 1- $NH,\ sin^2\theta_{23} = 0.6,\ \delta_{cp} = 3\pi/2$

Case 2- $NH,\ sin^2\theta_{23} = 0.4,\ \delta_{cp} = 3\pi/2$

Case 3 - $IH,\ sin^2\theta_{23} = 0.6,\ \delta_{cp} = 3\pi/2$

Case 4- $IH,\ sin^2\theta_{23} = 0.4,\ \delta_{cp} = \pi/2$

Thank you

Numerical Methodology

$$N^{0.4}_{S,\ NH} = \alpha \times N^{0.4,\ \nu}_{S,\ NH} + (1 - \alpha) \times N^{0.4,\ \bar{\nu}}_{S,\ NH}$$

$$N^{0.4}_{S,\ IH} = \alpha \times N^{0.4,\ \nu}_{S,\ IH} + (1 - \alpha) \times N^{0.4,\ \bar{\nu}}_{S,\ IH}$$

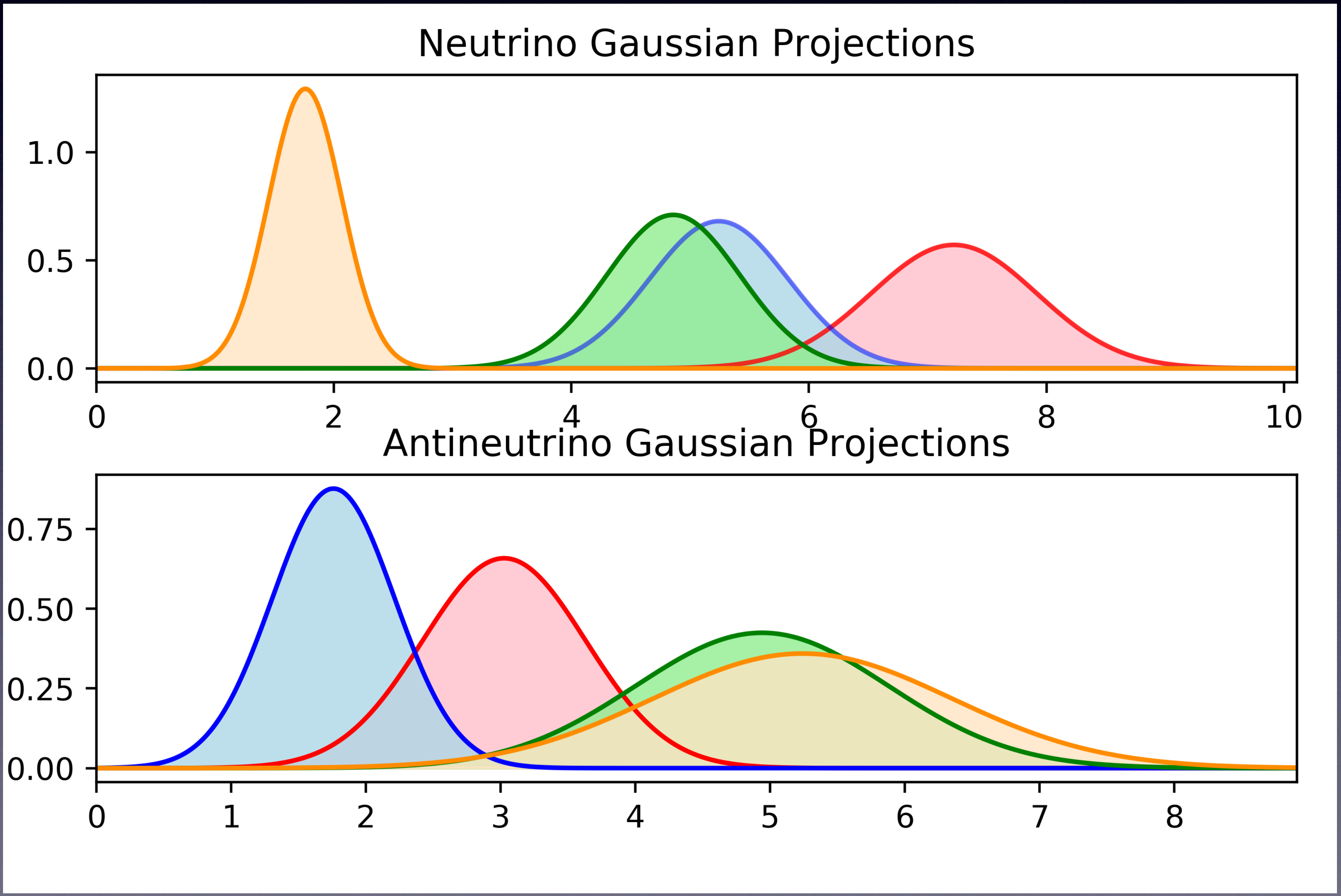
$$f(\alpha) = N^{0.4}_{S,\ NH} - N^{0.4}_{S,IH}$$

Numerical σ calculations

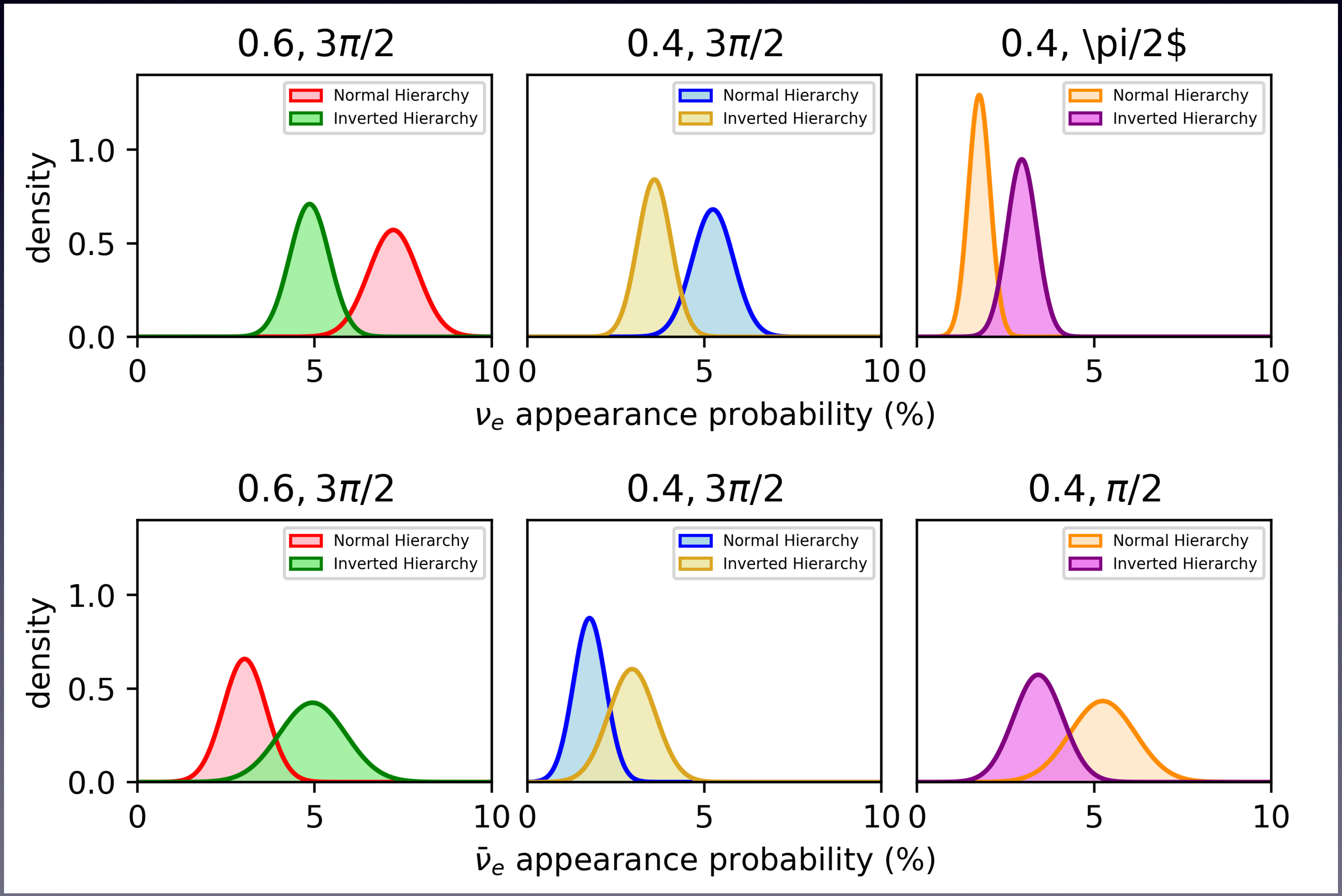
$$\sigma_{\nu\ or\ \bar{\nu}} = \frac{N_S}{N_S + N_B}\sqrt{\frac{1}{N_S} + \frac{1}{N_S + N_B}}$$

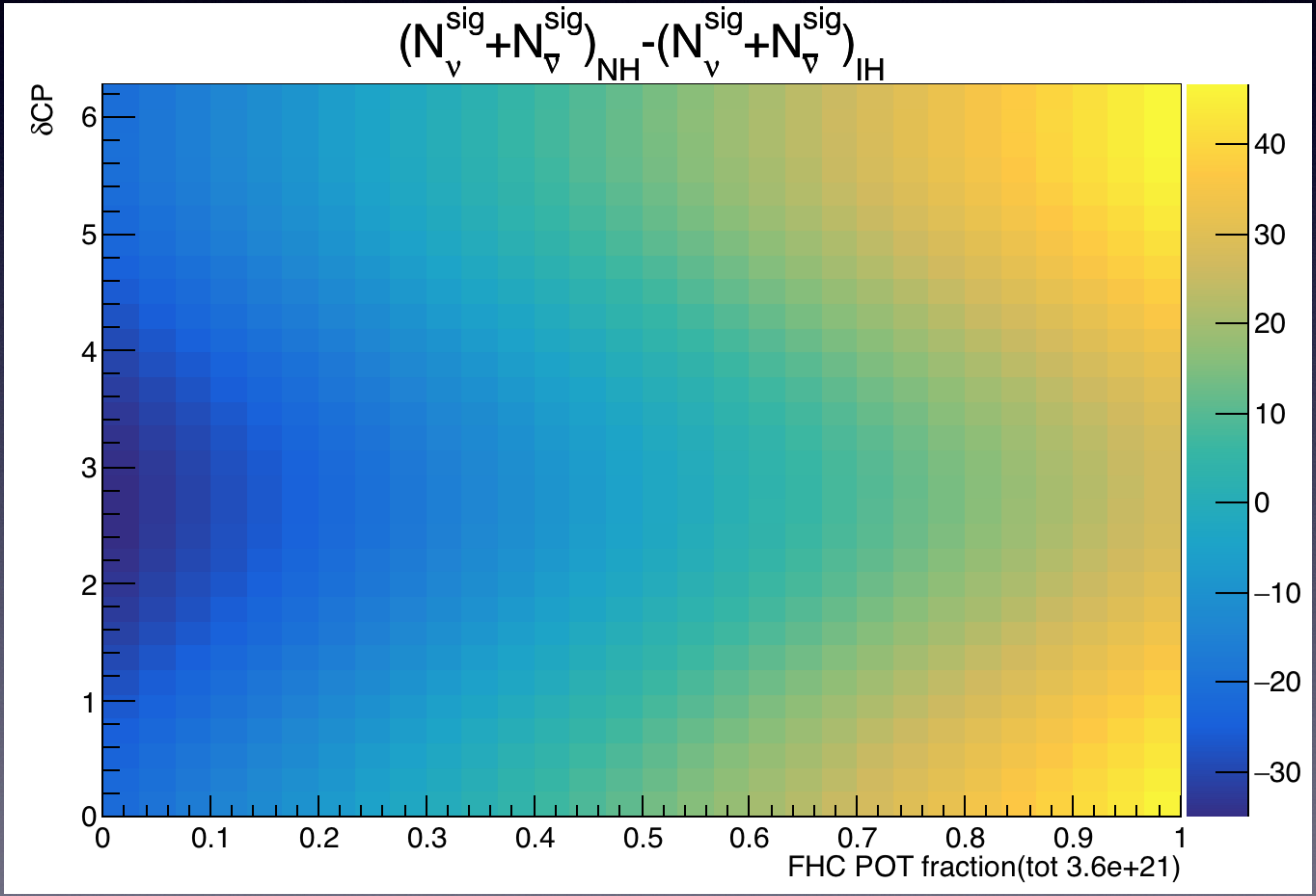
	neutrinos (%)	uncertainty (%)	antineutrinos (%)	uncertainty (%)
case 1	7.221	0.699	3.026	0.606
case 2	5.242	0.586	1.76	0.455
case 3	4.858	0.562	4.94	0.94
case 4	1.76	0.309	5.242	0.921

Results 2 - Projections of the general plot



If we compare the hierarchy in the same set of parameters…





$(N_{\nu}^{sig}+N_{\bar{\nu}}^{sig})_{NH}-(N_{\nu}^{sig}+N_{\bar{\nu}}^{sig})_{IH}$
δCP
0
1
2
3
4
5
6
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
FHC POT fraction(tot 3.6e+21)
40
30
20
10
0
−10
−20
−30