Update on ORCA Sensitivity Study
A Closer Look at the Octant Degeneracy

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ORCA Call
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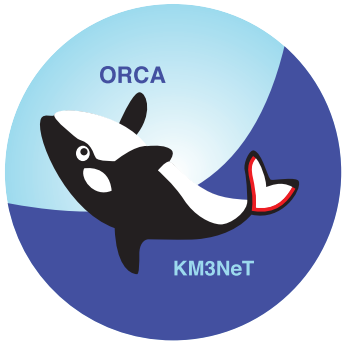
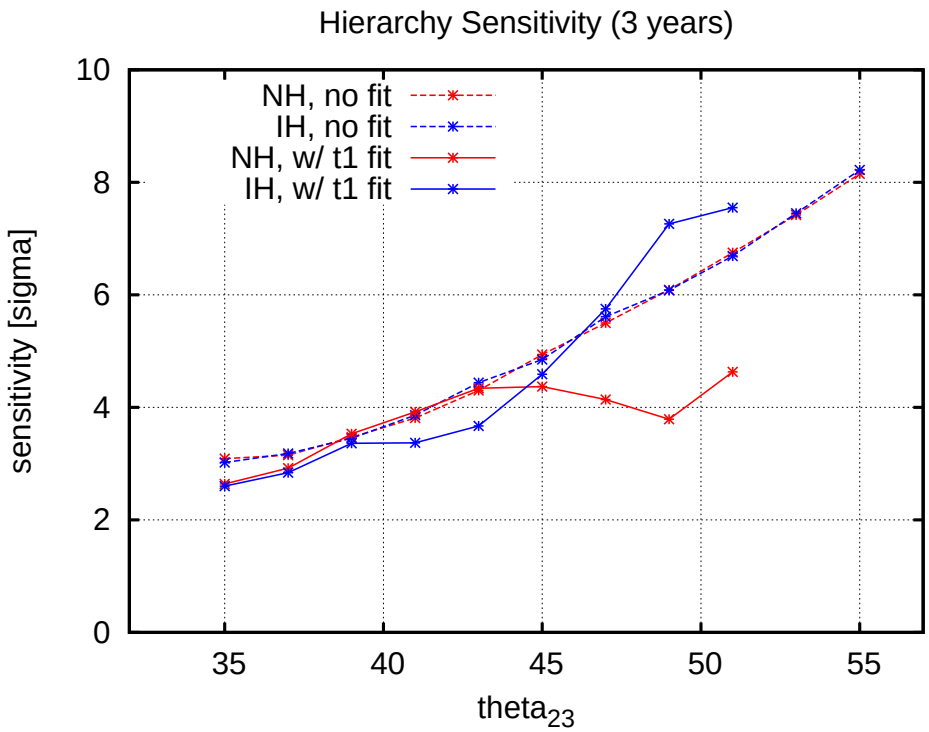


Introduction

- Octant and hierarchy are partly degenerate
- Started investigating in response to questions about sensitivity (e.g. why is the NH line above the IH line?)
- Found very interesting behaviour

Sensitivity as a function of θ_{23}

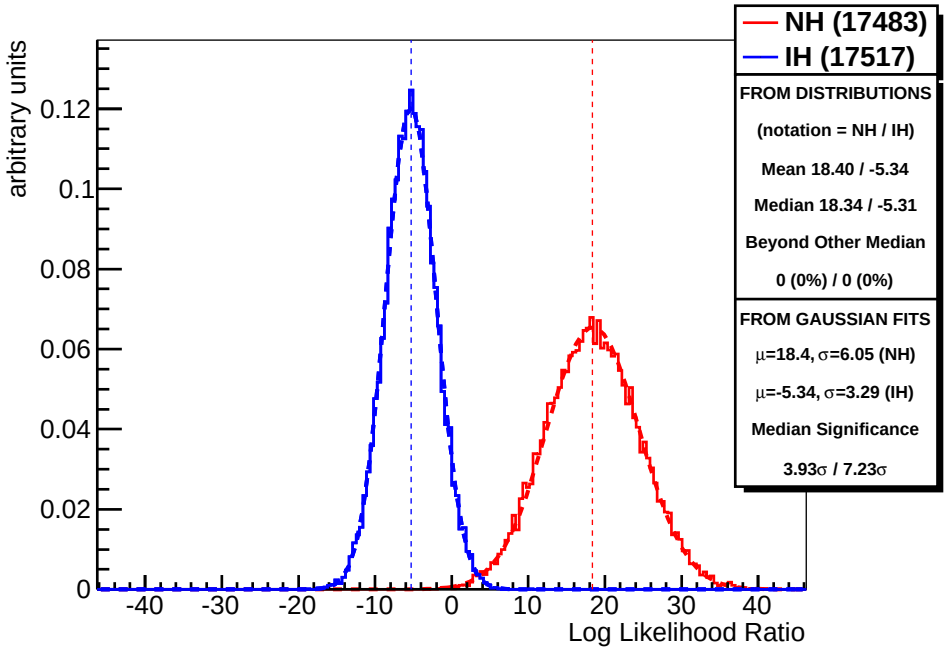
- This looks suspicious.
- Why do we get an asymmetry between NH and IH?
- Sensitivity with fit is sometimes higher than without fit - is that even possible?
- How to interpret these results?



Median hierarchy sensitivity as a function of θ_{23}. Dashed lines: not fitting θ_{23}. Solid lines: fitting θ_{23} (no prior).

Sensitivity as a function of θ_{23}

- See example LLR distributions on the right
- Distributions are still Gaussian but asymmetric

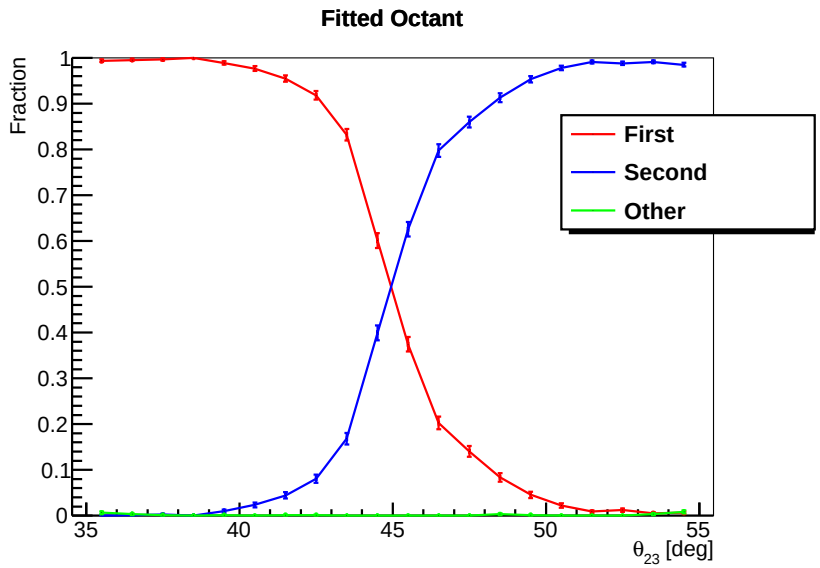


Example: LLR distributions corresponding to $\theta_{23} = 49°$ in the plot on the previous slide.

Octant Fit

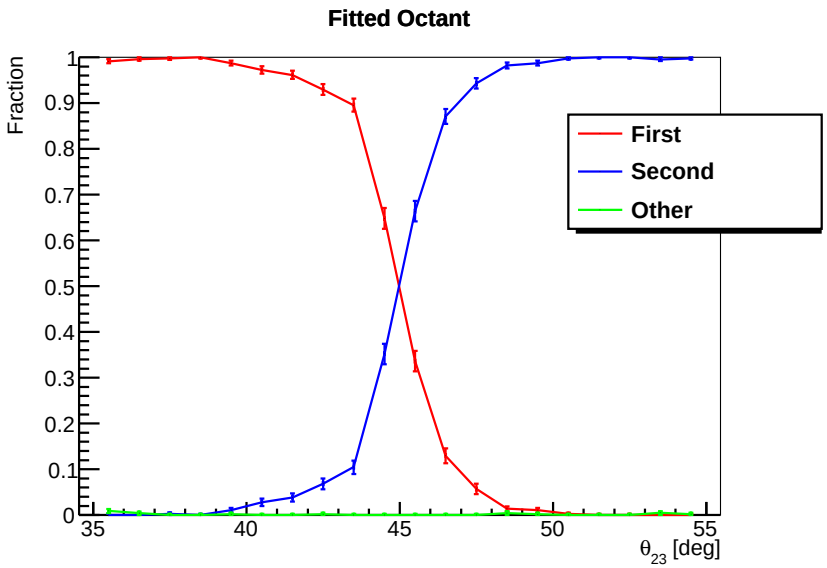
How well are we able to measure the octant?

- Valencia LoI model
- Fitting only hierarchy and θ_{23} (no prior)
- θ_{23} uniformly distributed from 35 to 55 degrees
- Other parameters fixed at true values
- Note that 'measuring the octant' is meaningless at 45 degrees
- Interesting: no problem at e.g. $\theta_{23} = 38°$ but hard at e.g. $\theta_{23} = 42°$.

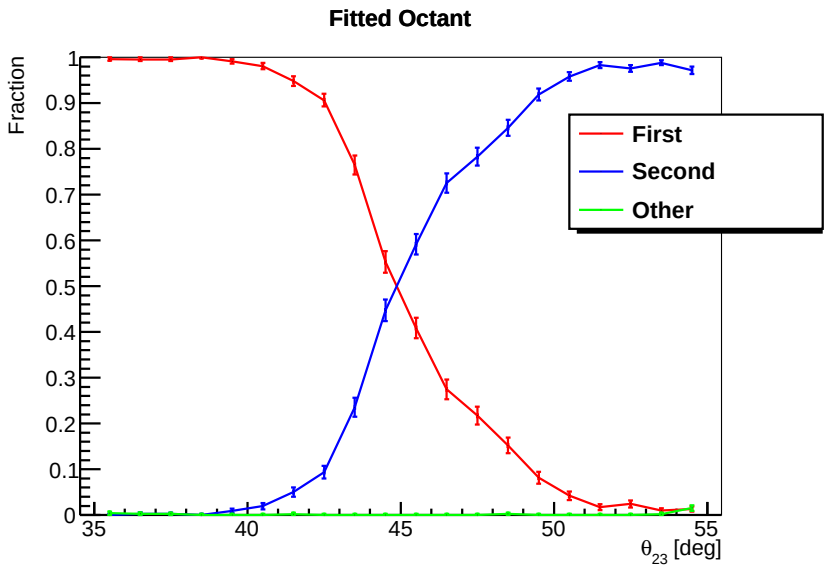


Fitted octant as a function of the true value of θ_{23}. The error bars show 1σ Bayesian confidence intervals for a binomial distribution.

Octant Fit



Selecting only **NH** *pseudo-experiments.*
More often wrong in first octant.

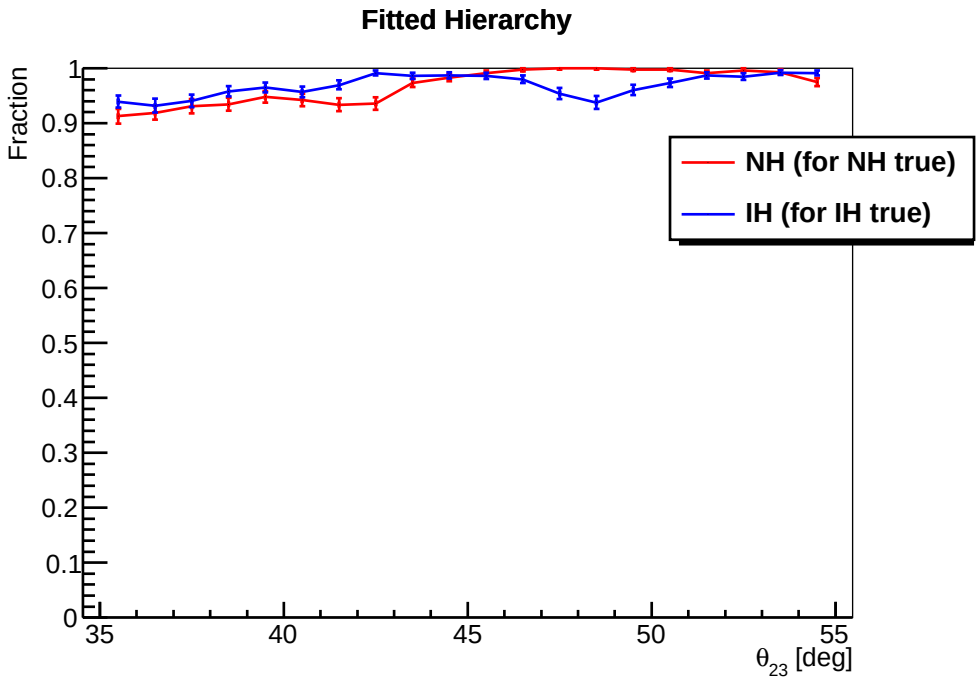


Selecting only **IH** *pseudo-experiments.*
More often wrong in second octant.

Hierarchy Determination

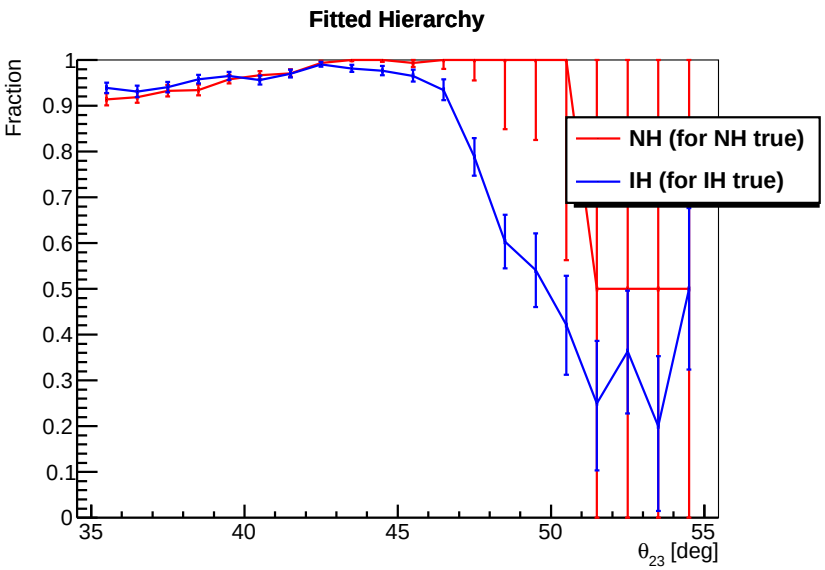
Here we see how often we fit the correct hierarchy as a function of θ_{23}

- We can already see a dependence on θ_{23}

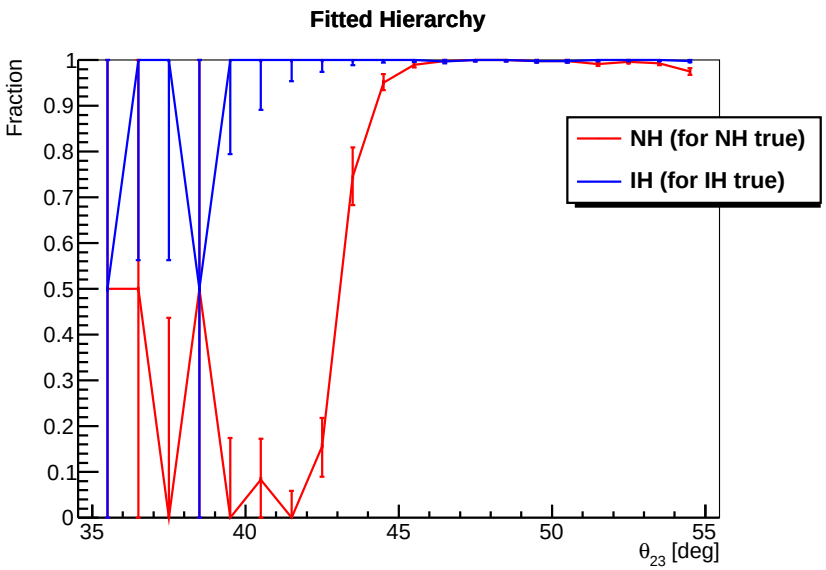


Fitted **hierarchy** *as a function of the true value of* θ_{23}.

Hierarchy Determination



Pseudo-experiments with
$\theta_{23,fit} < 45°$
*(***first octant fitted***)*
second octant IH looks like first octant NH

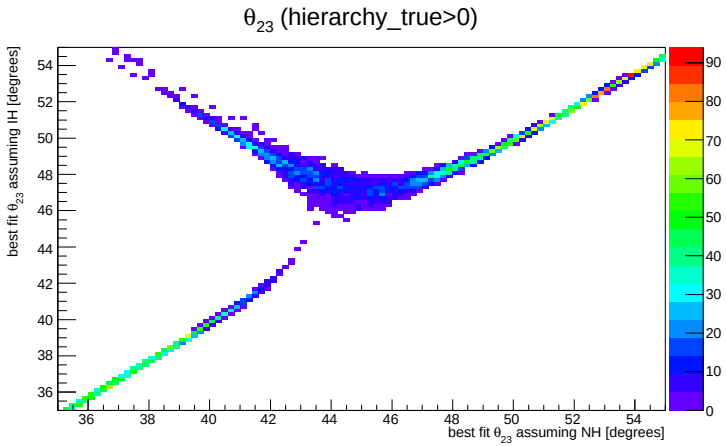


Pseudo-experiments with
$\theta_{23,fit} > 45°$
*(***second octant fitted***)*
first octant NH looks like second octant IH

The Explanation

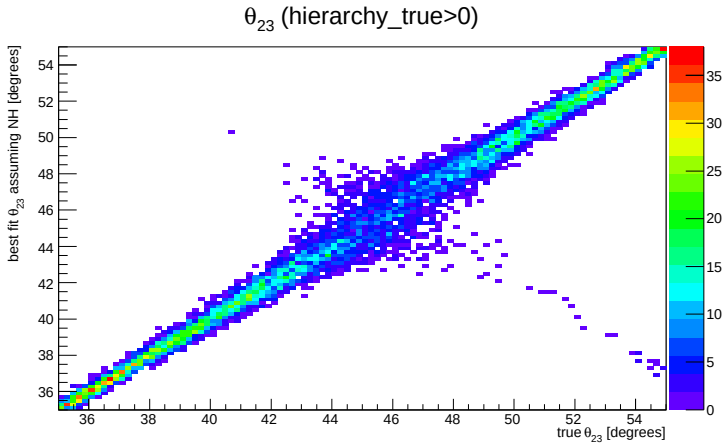
- Sensitivity based on distribution of log likelihood-ratio R
- $R = \log(L_{NH}/L_{IH})$
  where L_{NH} (L_{IH}) is the likelihood of the **best fit** assuming NH (IH).
- When calculating the LLR without fitting θ_{23} we compare NH and IH at **the same value** of θ_{23}.
- This is no longer the case when θ_{23} is free
- Assuming the right hierarchy the most likely θ_{23} is usually in the **right octant**
- Assuming the wrong hierarchy often gives θ_{23} in the **wrong octant**.
- $\Rightarrow$ we are comparing two very different numbers than before

Fitting θ_{23} for true NH

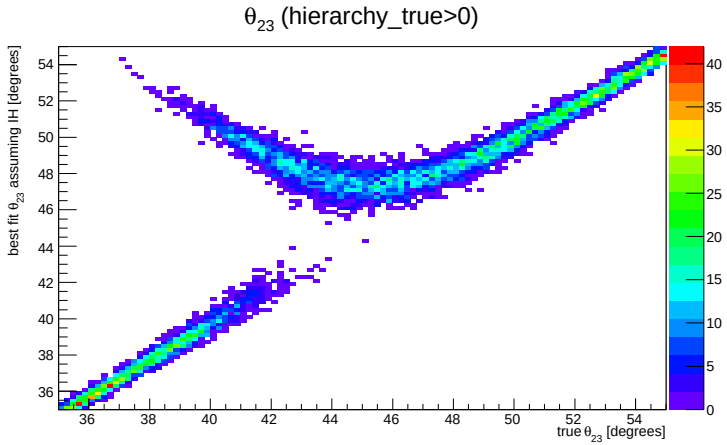


NH pseudo-experiments. Fitted θ_{23} when assuming NH versus the fitted θ_{23} when assuming IH.

- Here we select only NH pseudo-experiments
- Important region 40-45 degrees (first octant)
  $\Rightarrow$ here best fit for NH and IH are in different octants
  $\Rightarrow$ expect an impact on the LLR distribution

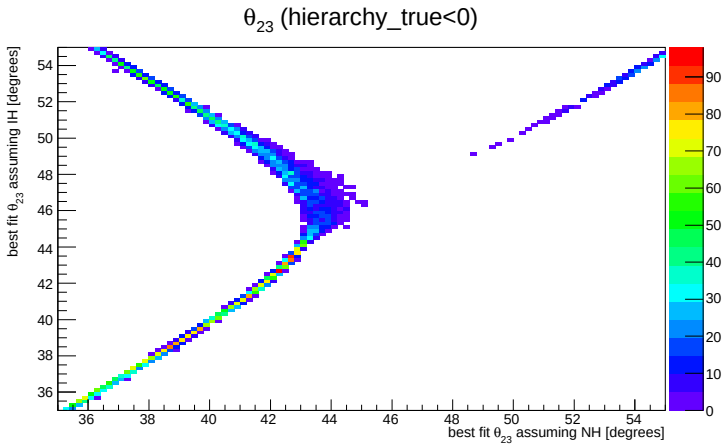


Fitting NH pseudo-experiments assuming NH.



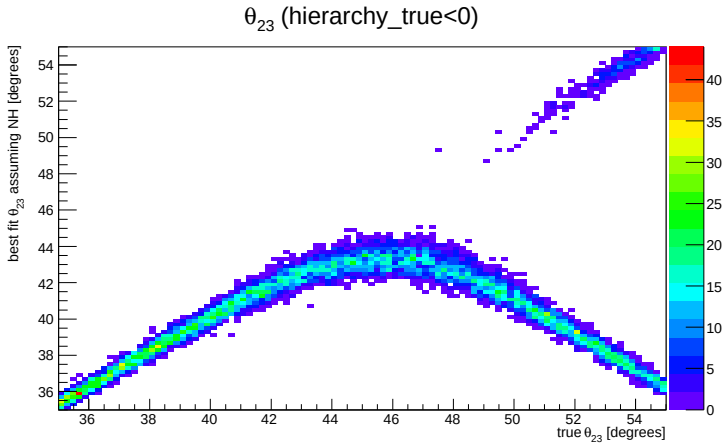
Fitting NH pseudo-experiments assuming IH.

Fitting θ_{23} for true IH

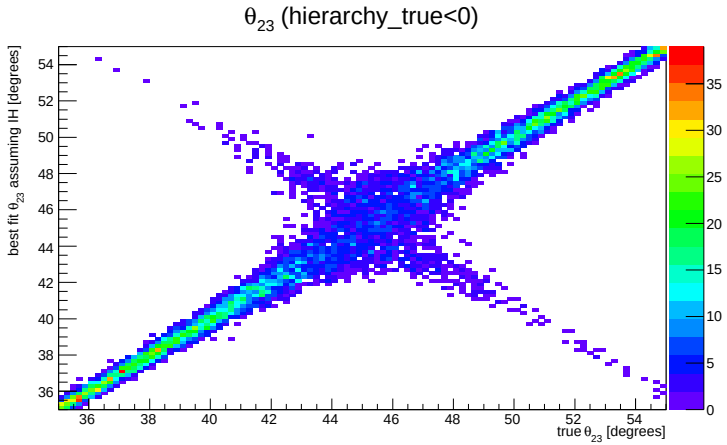


IH pseudo-experiments. Fitted θ_{23} when assuming NH versus the fitted θ_{23} when assuming IH.

- Here we select only IH pseudo-experiments
- Important region >45 degrees (second octant)
  ⇒ here best fit for NH and IH are in different octants
  ⇒ expect an impact on the LLR distribution



Fitting IH pseudo-experiments assuming NH.



Fitting IH pseudo-experiments assuming IH.

Answers to some Big Questions

- Is this even possible?
  - Yes it is.
  - I devised a simple model that shows the same behaviour (see attachment).
  - We can get asymmetric median sensitivities
  - One of them can even be higher than the sensitivity without a fit
- Are our previous results still correct?
  - Yes they are.
  - Our results are still valid. There is nothing wrong with the method and it was applied exactly as we always have.
- Is this a problem?
  - Not really
  - But it doesn't look very pretty
  - And people will need a lot of explanation to understand it.

Conclusions

- Good to know that these features exist
- Understand influence of θ_{23} on sensitivity better now
- Will try to find alternative, more intuitive way to represent the sensitivity to the hierarchy and the octant