Sensitivity to NMO with subdetectors

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Motivation

- Sensitivity to neutrino mass ordering (NMO) depends on the choice of fiducial volume (FV) cut R_{cut}
- Bigger R_{cut} leads to more statistics, but worse energy resolution and higher accidental background
- There are two options to deal with it:
  1. Find optimal R_{cut} to maximize JUNO sensitivity to NMO
  2. Separate the JUNO detector into several subdetectors and take into account features of each subdetector in the analysis
- The second option can lead to increase of JUNO NMO sensitivity since we can use statistics that would be discarded in the first option

Overview

- Analysis was performed with GNA software;
- Asimov dataset was used;
- Six years of data taking;
- JUNO detector was virtually divided into three parts with edges:
$R_1 \in [0\text{ m}, 15\text{ m}]$, $R_2 \in (15\text{ m}, 16.2\text{ m}]$, and $R_3 \in (16.2\text{ m}, 17.2\text{ m}]$

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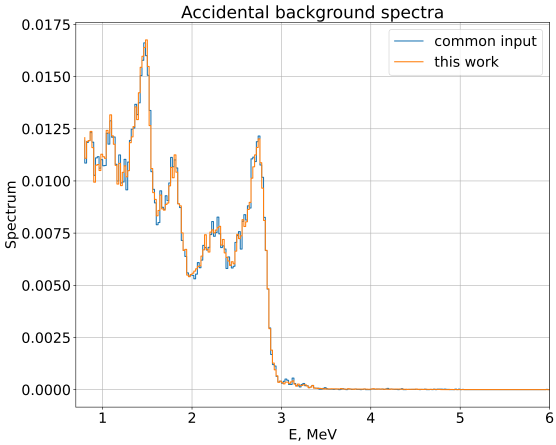
To perform subdetector NMO analysis one need to define subdetector related quantities:

- ✔ Fractions of IBD and backgrounds events in every subdetector and their correlations:
  - Fractions of uniformly distributed events (IBDs + all backgrounds except accidental);
  - Fractions of accidental background events;
- ⌛ Energy resolution and LSNL for the subdetectors. By now all subdetectors use the same energy resolution and LSNL from common input.

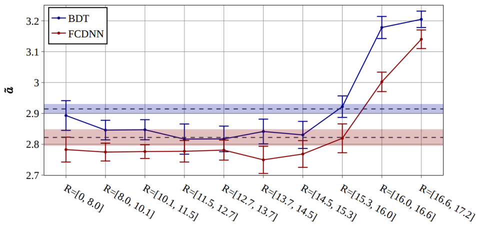
Note on accidental background

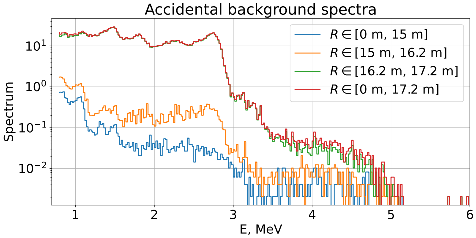
- This work uses accidental spectrum different from common input since common input has no spatial distribution of events
- The difference between spectra is small
- Impact on the sensitivity is $\Delta\chi^2 \sim 0.001$



Subdetector edges choice

1. $R \in [0\text{ m}, 15\text{ m}]$: lowest number of accidental events, the best energy resolution, 66.3% of FV;
2. $R \in [15\text{ m}, 16.2\text{ m}]$: low number of accidental events, slightly worse energy resolution, 17.2% of FV;
3. $R \in [16.2\text{ m}, 17.2\text{ m}]$: biggest number of accidental events, worst energy resolution, 16.5% of FV;





A. Gavrikov, Yu. Malyshkin, F. Ratnikov: „Energy reconstruction for large liquid scinitillator detectors with machine learning techniques: aggregated features approach" (Docdb: 8044)

Fractions of events

To define fractions of events:

1. Calculate initial fraction of events:
   - $\omega_i^{uni} = V_i/V_{tot}$ for uniformly distributed events;
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   where i denotes subdetector number;

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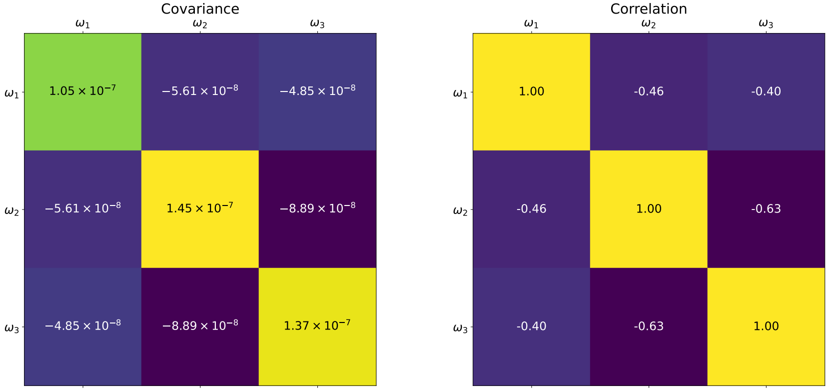
4. Recalculate fractions ω_i after shifting as $\omega_i = N_i/N_{tot}$;
5. Repeat steps 3-4 100’000 times so we have sample of fractions of events after shifting which allow us to calculate fractions covariance and correlation matrices;

Fractions of uniform events

- Uncertainties due to position reconstruction are about 10^{-5}

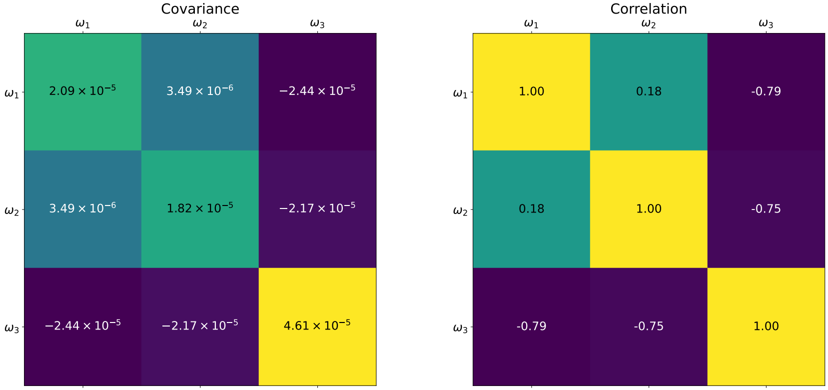
Obtained covariance and corerlation matrices for uniform events:



Fractions of accidental background events

- Uncertainties due to position reconstruction are about 10^{-3}

Obtained covariance and corerlation matrices for accidental events:



Current results

Three modes of the analysis:

- *nominal* mode: No division into subdetectors, analysis is the same as in the Dubna NMO technote (Docdb: 7489)
- *sum* mode: The detector is divided, but then all the spectra are summed. This mode should be consistent with nominal.
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$\Delta\chi^2$	nominal	sum	concat
data NO	8.0567	8.0567	8.1001
data IO	8.6184	8.6288	8.6711

$\Delta\chi^2 \sim 0.043$ sensitivity increase for NO

$\Delta\chi^2 \sim 0.053$ sensitivity increase for IO

Conclusion

- Subdetector NMO sensitivity analysis was performed;
- Events spill in/spill out between subdetectors due to JUNO spatial resolution is taken into account;
- By now, NMO sensitivity is increased by $\Delta\chi^2 \sim 0.043$ and $\Delta\chi^2 \sim 0.053$ for NO and IO respectively;
- WIP: Estimate energy resolution and LSNL for every subdetector that can lead to better results;