Status of Atmospheric Flux-Weighted ν_e - ^{16}O Cross-Section Measurement Below 125 MeV in Super-Kamiokande

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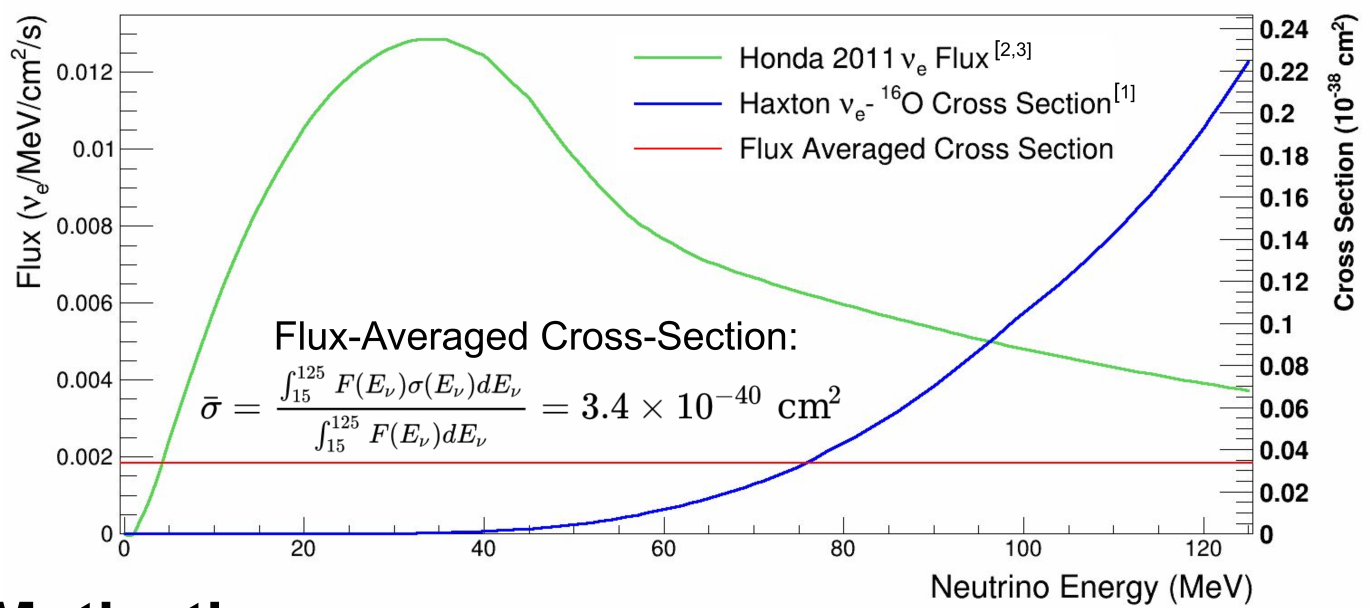
The Interaction: $\nu_e + {}^{16}\mathrm{O} \rightarrow e^- + {}^{16}\mathrm{F}^*$

- Neutrino energy threshold is at 15 MeV
- Using atmospheric neutrinos as a ν_e source, leading to a flux-weighted measurement between 15-125 MeV neutrino energy

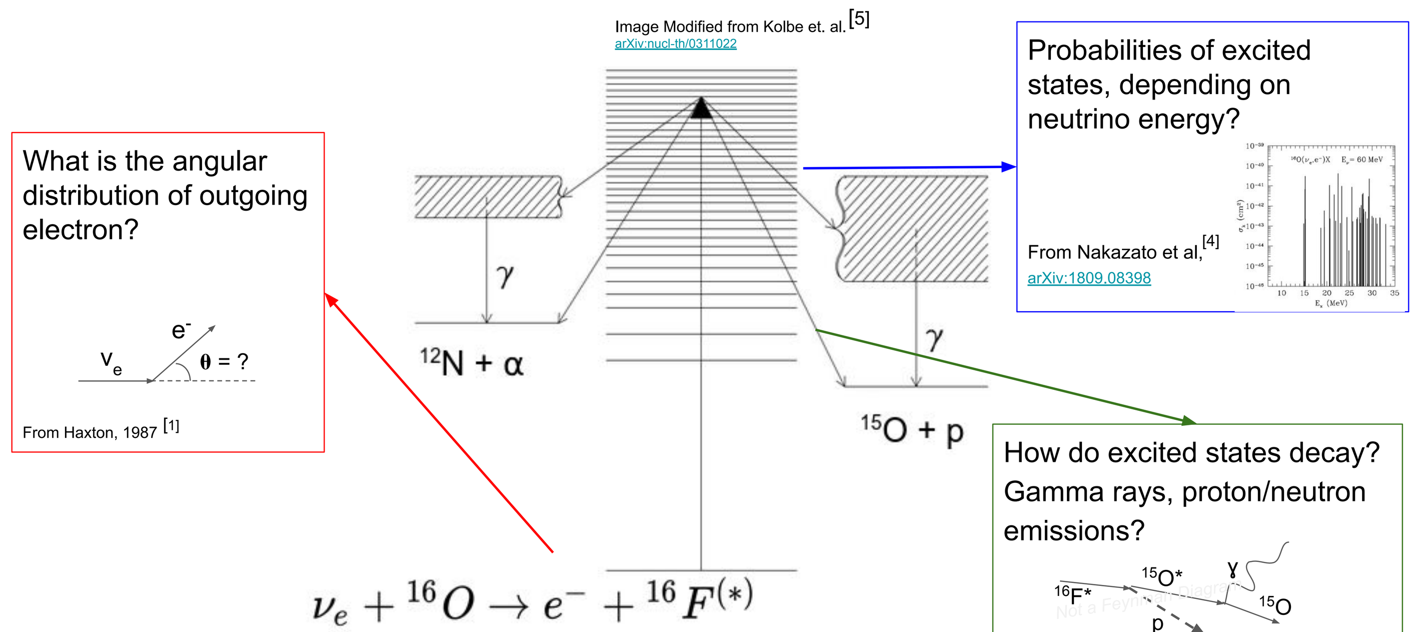


Motivation

- No previous measurement of this cross-section below 125 MeV
- ν_e detection channel in a supernova burst
- Background to DSNB searches
- Way to probe the low energy atmospheric neutrino flux

Event Generator

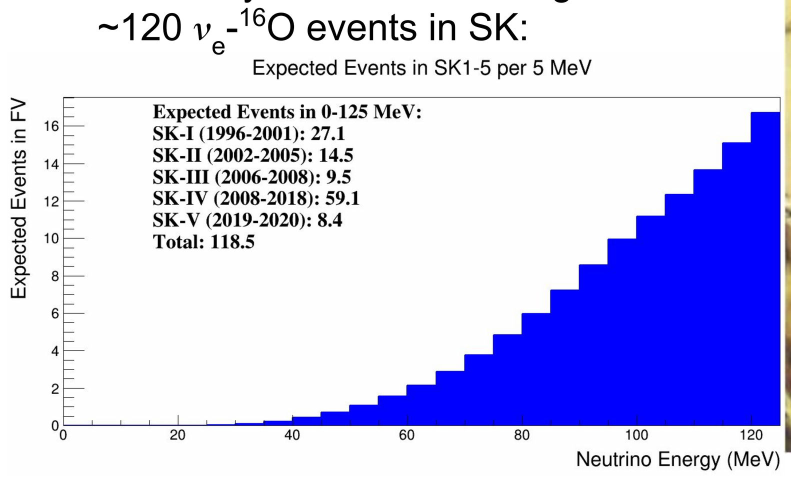
A custom event generator is developed to generate ν_e-^{16}O interactions below 125 MeV neutrino energy

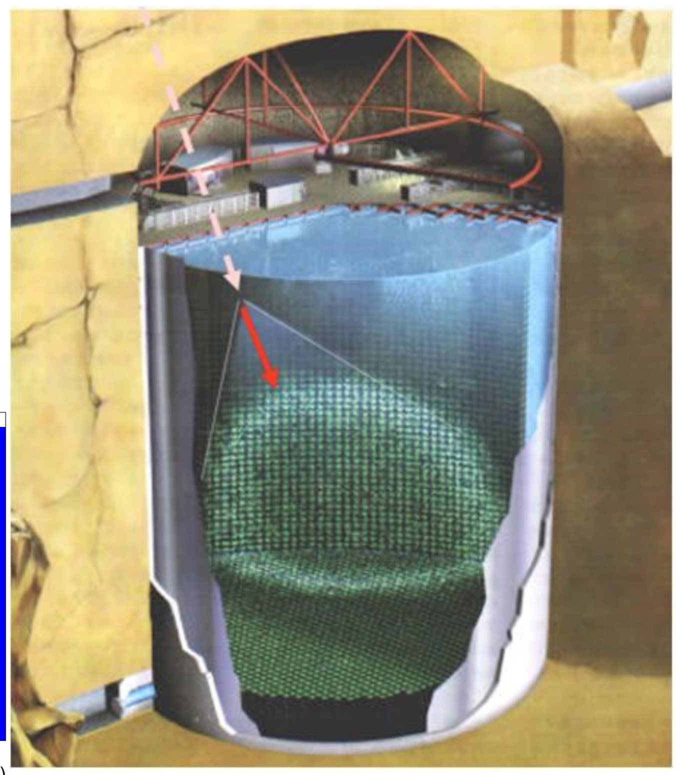


- Same questions for: $\bar{\nu}_e + {}^{16}O \rightarrow e^+ + {}^{16}N^{(*)}$
- Combine this info and build a custom event generator:
  - https://github.com/itscubist/newton [7]
- Good up to ~125 MeV neutrino energy

Super-Kamiokande Detector [8]

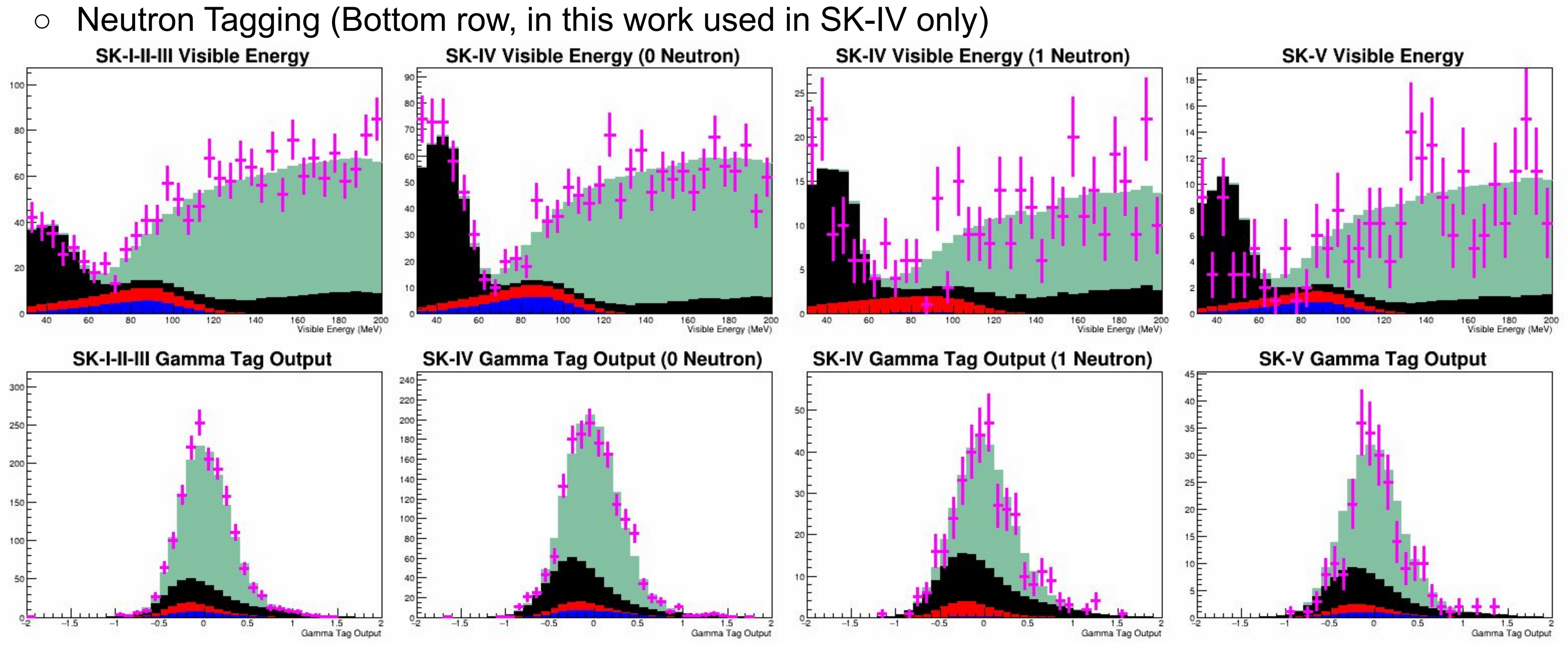
- 50 kTon - 22.5 kTon fiducial - Water Cherenkov Detector
- 11000+ PMTs
- Neutron tagging capabilities for SK-IV and later [9]
- Over 20 years of data taking results in ~120 ν_e-^{16}O events in SK:

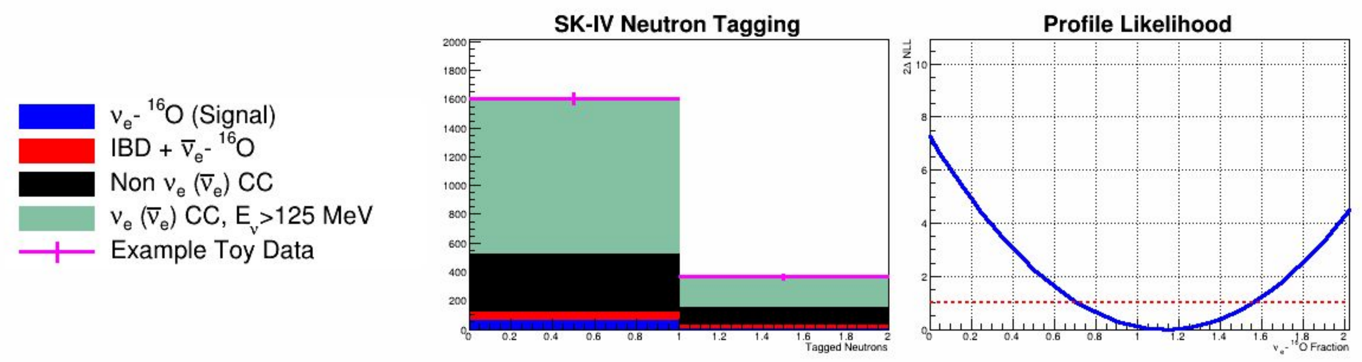




An atmospheric flux-weighted charged-current ν_e-^{16}O cross-section measurement for neutrinos below 125 MeV energy is underway with SKI-V data. ν_e-^{16}O cross-section in this energy range is not measured at all. Using visible energy spectrum, neutron tagging and newly developed gamma tagging we estimate that we can extract ν_e-^{16}O cross-section with 40% statistical error.

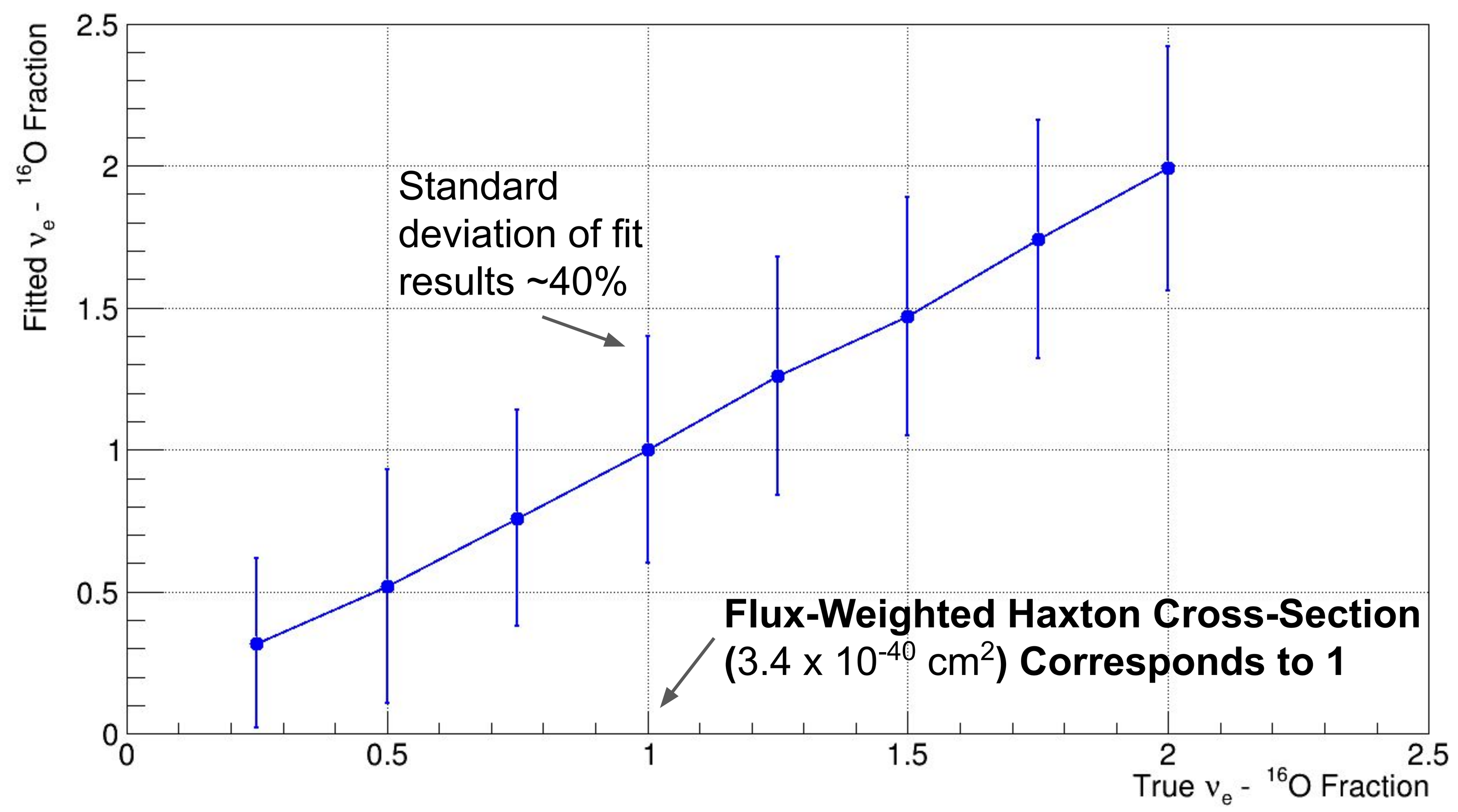
- Fit performance is studied with randomly generated toy datasets, an example is below.
- Fit output is the ratio of observed ν_e-^{16}O events to the predicted events by Haxton cross-section.
- Number of events for background templates (red, black, green) are also left free in the fit.
- Three observables are used in the fitting:
  - Visible Energy (Top row)
  - Gamma Tagging (Middle row)
  - Neutron Tagging (Bottom row, in this work used in SK-IV only)





Fit output is the ratio of observed ν_e-^{16}O events to the predicted events by Haxton cross-section.

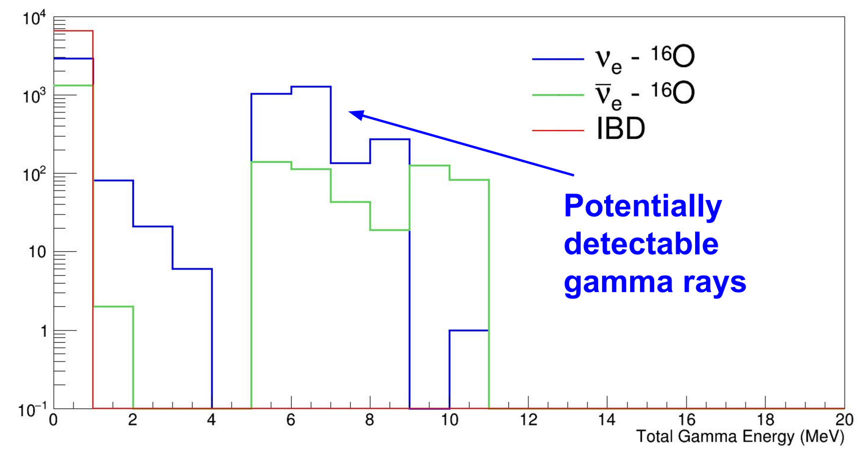
On the left is the profiled likelihood as a function of ν_e-^{16}O cross-section ratio for the example toy dataset above.



- X-axis is the ratio of cross-section used in generation of toy datasets to the one predicted by Haxton.
- For each data point 1000 toy datasets are generated based on their x-axis value and fitted.
- Y-axis is the cross-section ratio to the Haxton prediction extracted by the fitter (average of 1000 fits).
- Error bars indicate the standard deviation of 1000 fit results, as an estimation of statistical error for 1 fit.
- The linear relationship indicates flux-weighed cross-section can be measured correctly.

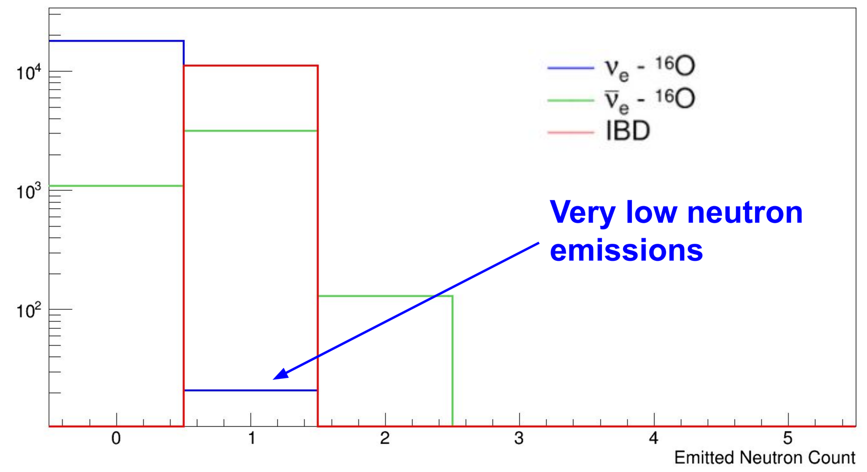
Gamma & Neutron Emissions

Difference in gamma and neutron emissions of ν_e-^{16}O from backgrounds such as IBD, $\bar{\nu}_e$-^{16}O and Michel electrons is critical for this measurement.



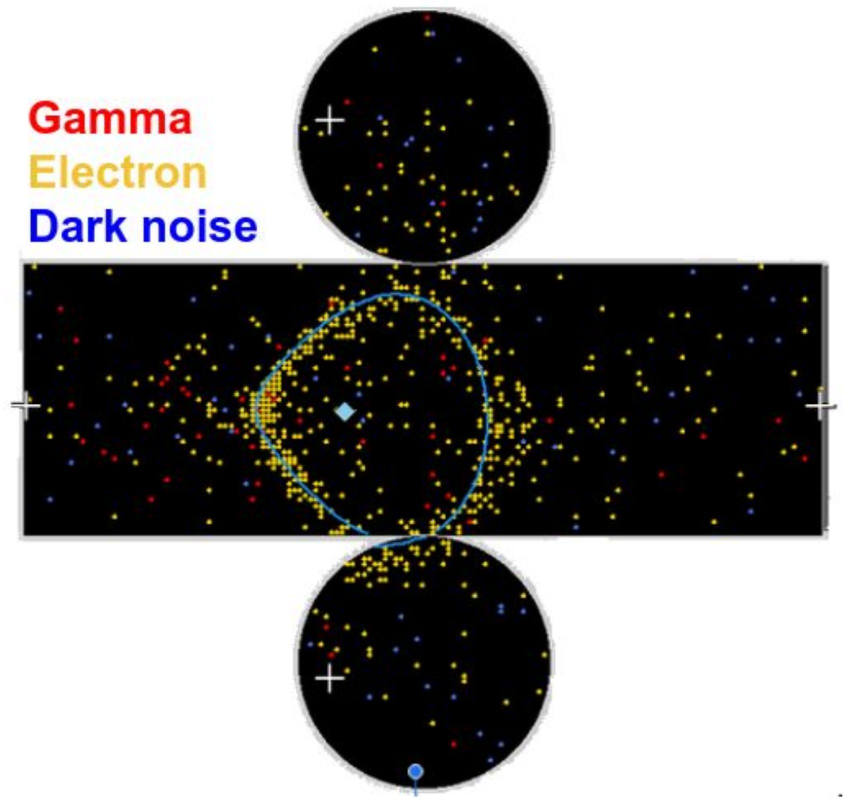
50% of ν_e-^{16}O events (blue) have gamma rays above 3 MeV emitted from nuclear de-excitations.

^{16}F* is proton rich so almost no neutron emissions from its decays are expected (supported by TALYS)



Gamma Tagging

Can we identify hits due to gamma rays (red) alongside the hits due to main electron signal (orange)?



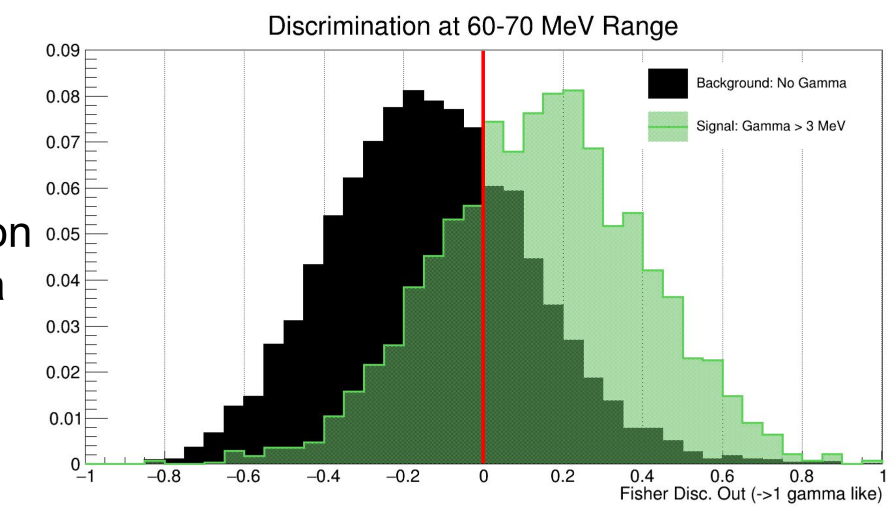
MC ν_e-^{16}O event: A 90 MeV electron accompanied by 3 gamma rays (total of 10 MeV) in SK

Use a multi-variable approach:

- # of hits outside the Cherenkov ring
- Isotropy of hits
- Timing and position distribution of hits

Combine variables with a Fisher Discriminant trained separately for each SK phase for 1 ring e-like events.

On the right: Discrimination for events with no gamma rays (black) and with gamma rays (green)



Next Steps

- Incorporate systematic errors that will affect the shapes of the templates used in the fitting
- Open data and perform fit to SKI-V data.

References

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