Evaluation of the Position and Direction Dependence of the Energy Scale Using the Decay of ^{16}N at Super-Kamiokande

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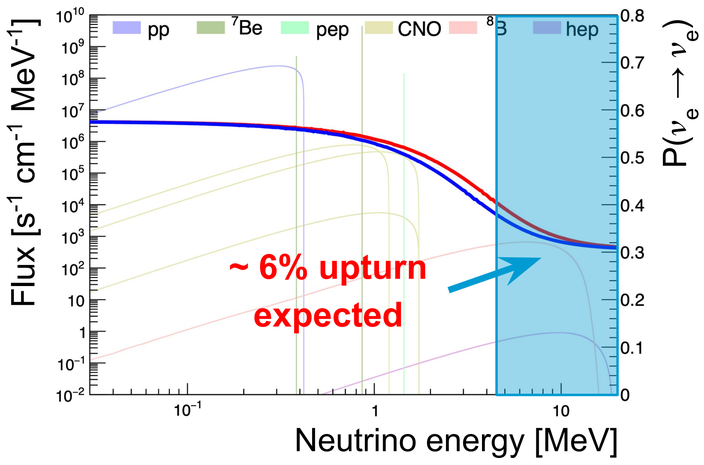
Poster #312

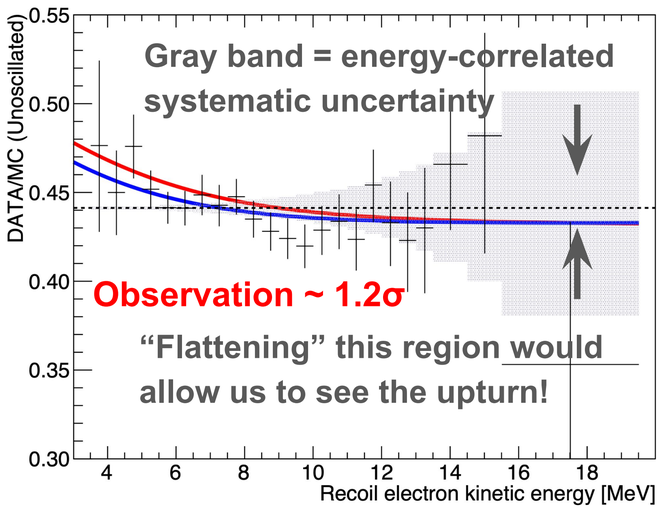
We Are Not Yet Done With Solar Neutrinos

- Since the beginning of data taking, Super-Kamiokande (SK) has been conducting ground-breaking studies of solar neutrinos [1].
- All measurements to date are consistent with solar neutrino flavor change due to matter enhanced neutrino oscillations [Poster #512].



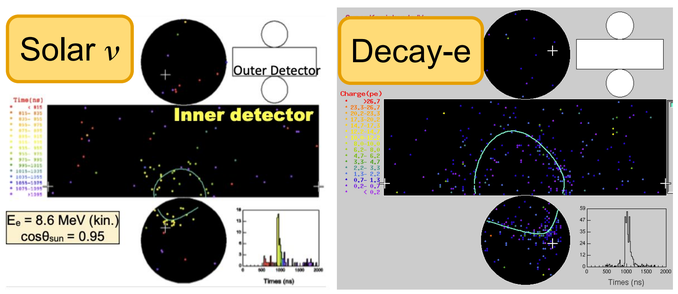
So, What's the Matter?

- Well, a key phenomena yet to be observed is the **energy dependence in the electron neutrino survival probability**, driven by matter effects in the Sun (also called the "spectral upturn").



9-to-5 as an Experimentalist: Calibration!

- Of course, this is not entirely true, but precise energy calibration is essential to reach the required sensitivities for the solar neutrino spectral upturn.
- A typical low-energy event (3.5-100 MeV) records 1 hit per PMT



- The energy of low-energy events is reconstructed based on the number of PMT hits alone, that is further converted into an **effective number of hits**:

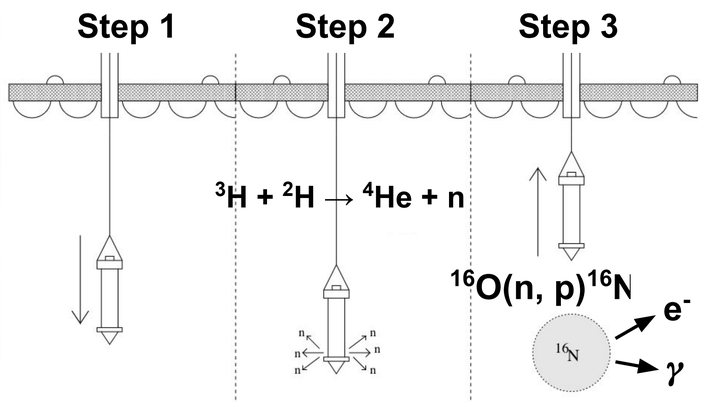
$$N_{eff} = \sum_{i}^{N_{50}} \left[(X_i) + \epsilon^i_{tail} - \epsilon^i_{dark} \right) \times \frac{N_{all}}{N_{alive}} \times \frac{S(0,0)}{S(\theta_i, \phi_i)} \times \exp\left(\frac{r_i}{L^i_{eff}}\right) \times \frac{G_i}{QE_i} \right]$$

Multiple photoelectrons; Photon reflection and scattering; Dark rate; Effective PMTs; Photon entry angles; Water transparency; PMT gain and QE

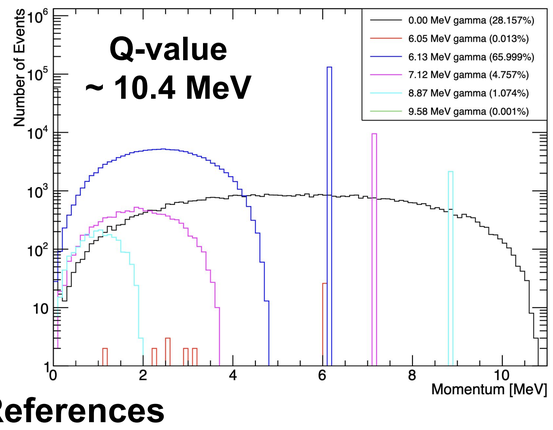
- How much this energy reconstruction varies based on interaction positions and directions in the detector is considered the **systematic uncertainty of the energy scale**.

^{16}N as a Calibration Source

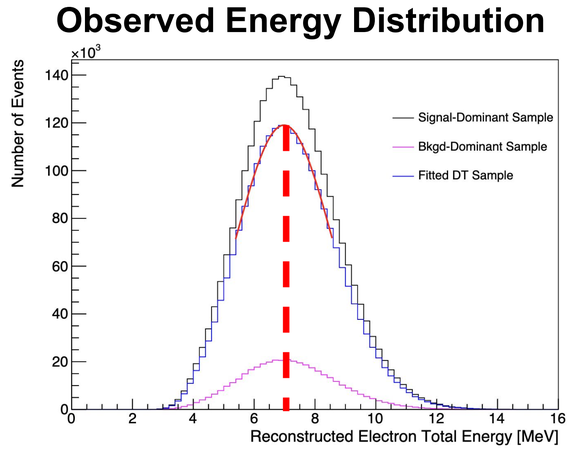
Deutrium Tritium Generator (DTG) [2]



Energy Spectra of ^{16}N Decay [3]

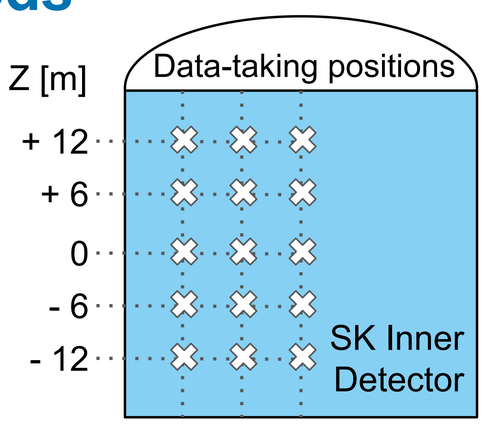


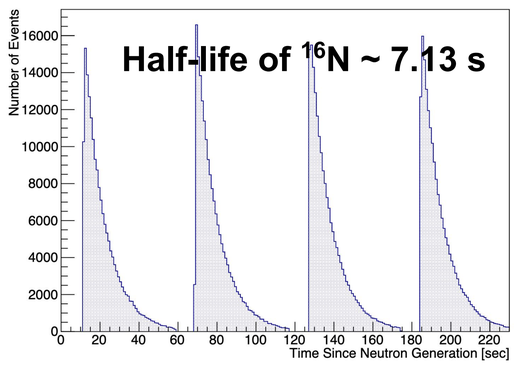
Observed Energy Distribution



References
[1] K. Abe et al., Phys. Rev. D 109, 092001
[2] E. Blaufuss et al., Nucl. Instrum. Meth. A 458, 638 (2001)
[3] S. Agostinelli et al., Nucl. Instrum. Meth. A 506 (2003)

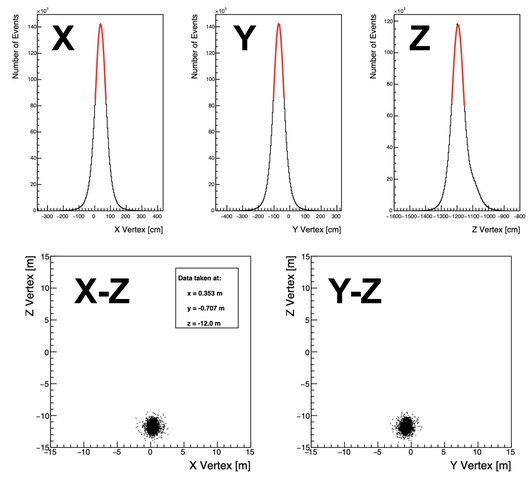
Methods





Data

1. Apply basic cuts
   - Energy cut
   - Distance from wall and DTG
2. Background subtraction
   - For each firing, subtract the last 20 sec (bkgd-dominant) from the first 20 sec (signal-dominant)

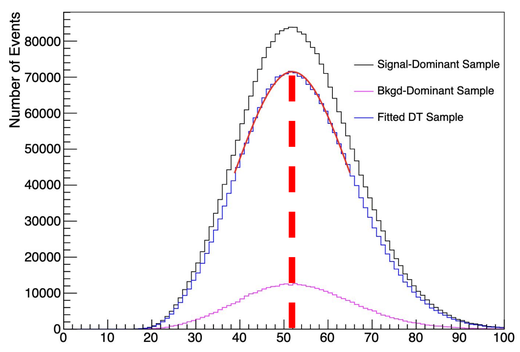


MC Simulation

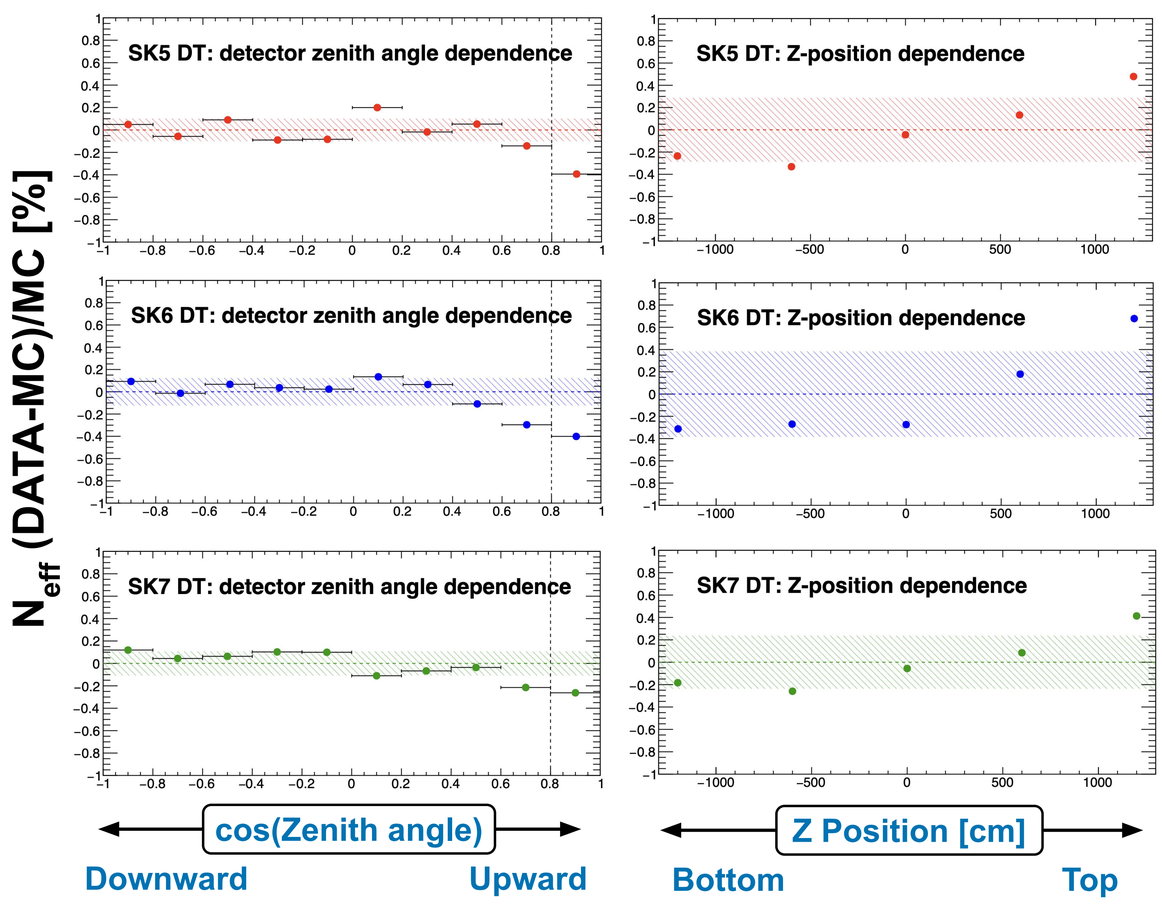
3. Generate electron and γ at the same position as the data sample

Calibration Parameter

4. Take the mean value of the number of effective hits and its data-MC ratio: (Data-MC)/MC [%]



Results



	SK Operational Phases		
Uncertainty	**SK-V**	**SK-VI**	**SK-VII**
Direction Dependence	**± 0.10%**	**± 0.12%**	**± 0.11%**
Position Dependence	**± 0.29%**	**± 0.38%**	**± 0.24%**

Summary

Energy calibration using ^{16}N events was performed in the pure-water and gadolinium-loaded phases of Super-Kamiokande. Systematic uncertainties of the energy scale were evaluated to be up to 0.4% for the position dependence and up to 0.2% for the direction dependence. These results are comparable to the level obtained in the previous phases and can be further reduced to observe the long-sought-after solar neutrino matter effects.