The Diffuse Supernova Neutrino Background at Super-Kamiokande

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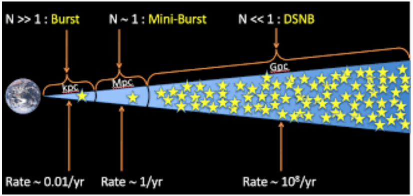
The Diffuse Supernova Neutrino Background

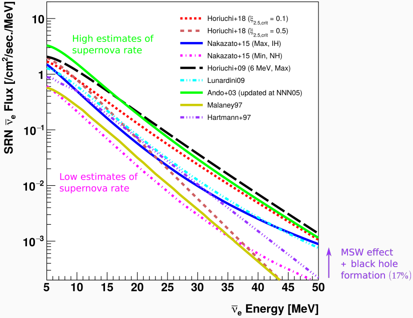
Neutrino flux from all distant core-collapse supernovae



J. Beacom

2-3 galactic supernovae/century

1 SN/s in the observable Universe



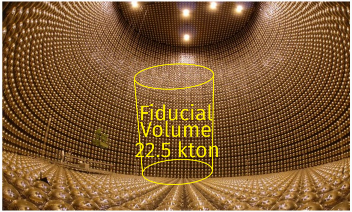
Y. Ashida

- Detection and characterization would allow for the study of aggregate properties of core-collapse supernovae, while probing the history of the universe and neutrino properties
- All flavors of neutrinos produced during CC SN, reaching Earth redshifted
- Expected signal is $\sim$10s of MeVs and has so far proved elusive

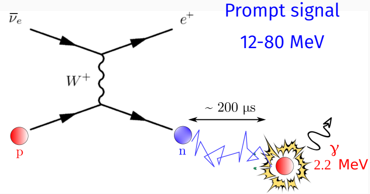
The search for the DSNB at SK

Detection of DSNB $\overline{\nu_e}$ via Inverse Beta Decay (IBD) in water

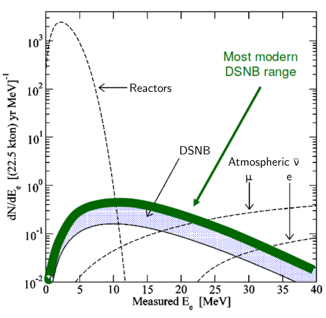
- **Super-Kamiokande**: a 50-kton water Cherenkov detector in Kamioka, Japan



- 5-20 events/year
  Energy range: 12-80 MeV
- Need extremely powerful algorithms to characterize spallation and atmospheric backgrounds and **identify the neutrons**
- Current analysis: uses runs from the **SK-IV** data-taking era (Sep 2008-May 2018)



Weak delayed signal



[Beacom and Vagins, Phys. Rev. Lett., 93:171101, 2004]

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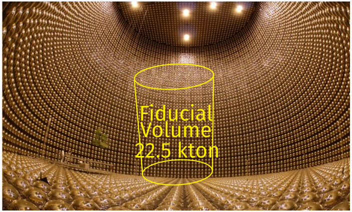

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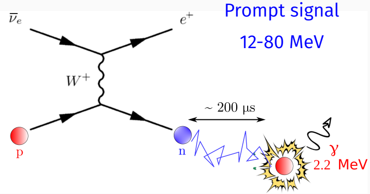
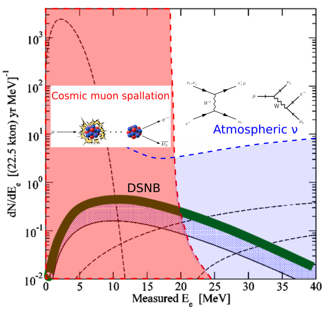


Prompt signal

12-80 MeV

Weak delayed signal



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The SK-IV DSNB Analysis: the 3 pillars

→ Three key steps for the analysis after simple noise reduction:

1. Spallation cuts

Remove radioactive isotopes produced by cosmic muons

$\mathcal{O}(10^4)$ reduction required

Look for **correlations** in the event topologies of incoming muons and candidate events, **over large timescales** (up to 13 s)

2. Atmospheric background reduction and characterization

Remove atmospheric neutrinos events containing pions/muons/photons

Estimate the spectral shapes of remaining low-energy atmospheric backgrounds

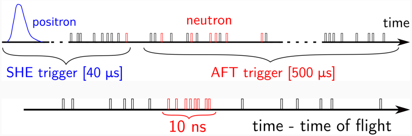
3. Neutron tagging

New in SK-IV analysis

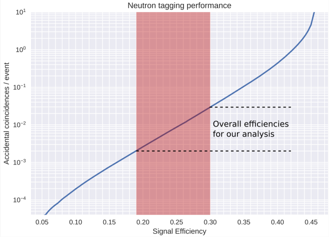
Identify the delayed signal from the neutron capture in water

Neutron tagging

A faint neutron capture signal amid a sea of low-energy background



- **New SK-IV trigger scheme** dramatically extends search time window, making the detection of neutron captures in water ($\tau_{\text{CAP}} \sim 200$ns) feasible.
- The **2.2 MeV neutron capture** signal is extremely weak and easily lost among the abundance of low-energy backgrounds (4 kHz PMT noise, radioactivity, flasher events...)
- Up to $\mathcal{O}(10^4)$ reduction required after candidate selection

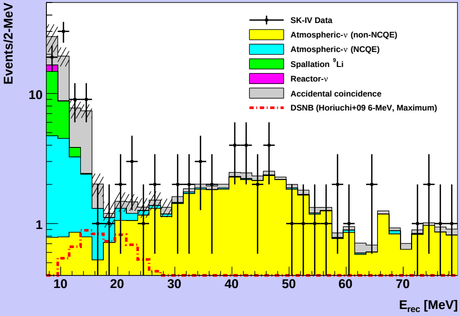


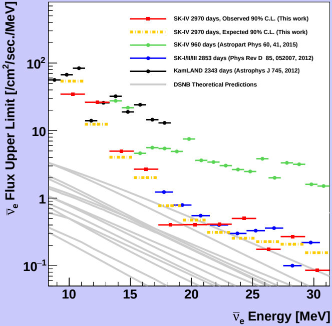
- Maximally exploit correlations with well-reconstructed primary vertex
- Use a BDT (a Machine Learning method) to classify neutron candidates, achieving ∼20%-30% overall efficiency

⋆ Gd has recently been dissolved inside the tank, producing **brighter, 8 MeV capture signals**. Efficiency is expected to increase to >80% for future analyses.

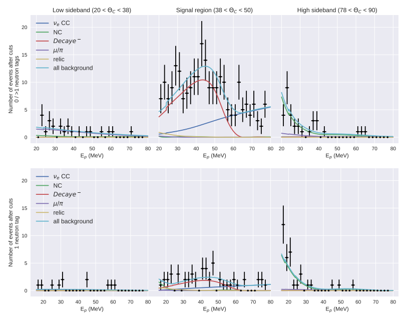
Latest results with SK-IV data

Binned, model-independent





Unbinned spectral fit



$\overline{\nu_e}$/cm^2/s > 17.3 MeV	90% CL upper limit			Pred.
Model	**SK4**	**SK1-4**	**Sens.**	
Kaplinghat+00, max	3.7	2.6	1.3	3.00
Horiuchi+09 6 MeV, max	3.8	2.7	1.5	1.94
Ando+03 (updated 05)	3.8	2.7	1.5	1.74
Kresse+20 (High, NH)	3.7	2.7	1.5	1.57
Lunardini09 Failed SN	3.8	2.7	1.5	0.72
Nakazato+15 (max, IH)	3.8	2.7	1.5	0.53

Conclusion

- Analysis of the full SKIV dataset complete, wholly integrating neutron tagging for the first time. This is to be fully capitalized on in Super-K Gd.
- Current limits are close to theoretical predictions, with 90% CL sensitivity comparable to some optimistic models, which are not excluded due to an observed (non-significant) excess. Promising outlook for analysis with Super-K Gd
- Looking ahead: the larger statistics afforded by Hyper-K, as well as combined efforts with other neutrino observatories, will allow for more precise characterization of the DSNB

Thanks for your time!