SK-Gd: Detecting Pre-supernova Neutrinos

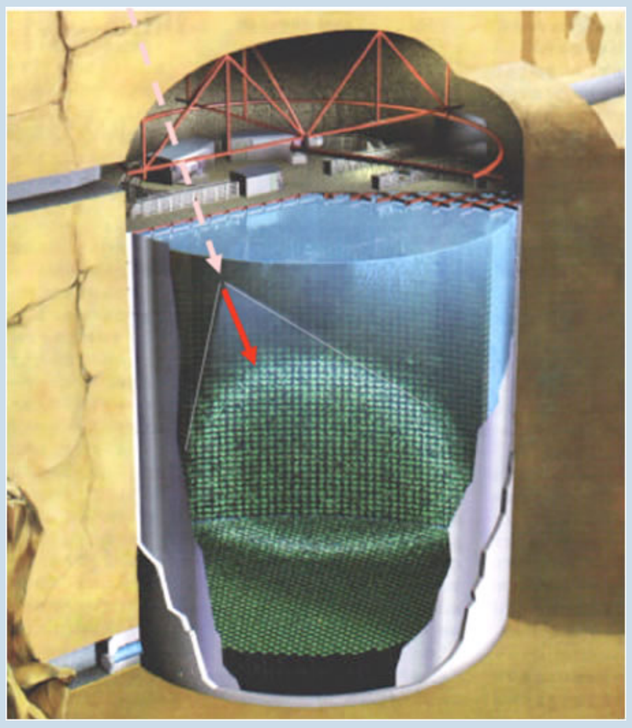
Charles Simpson
charles.simpson@physics.ox.ac.uk

Super-Kamiokande

- 50ktons water, 22.5 kton fiducial volume
- Instrumented with 11129 20 inch PMTs
- Detects Cherenkov light from charged particles passing though water

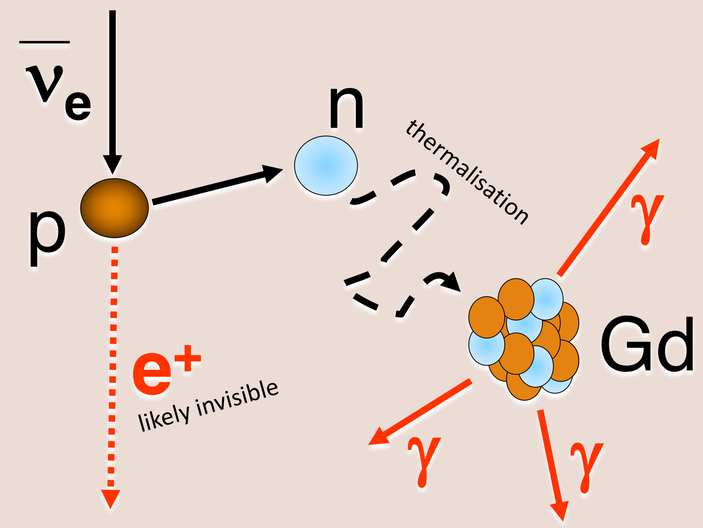
- Studies atmospheric and solar neutrinos
- Far detector for T2K
- Waiting for supernova detection

- Soon to be upgraded for next phase with Gadolinium doping
- By adding 0.2% Gd salt by mass, will detect 80% of neutrons [1].



Thermal Neutron Capture on Gadolinium

- Naturally occurring isotopes of Gadolinium have some of the highest cross sections for **thermal neutron capture**[1].
- Neutron capture followed by **gamma ray cascade** of around 8 MeV within 20 microseconds; enough energy to be reliably detected in Super-K.
- Allows **events containing neutrons** to be identified.

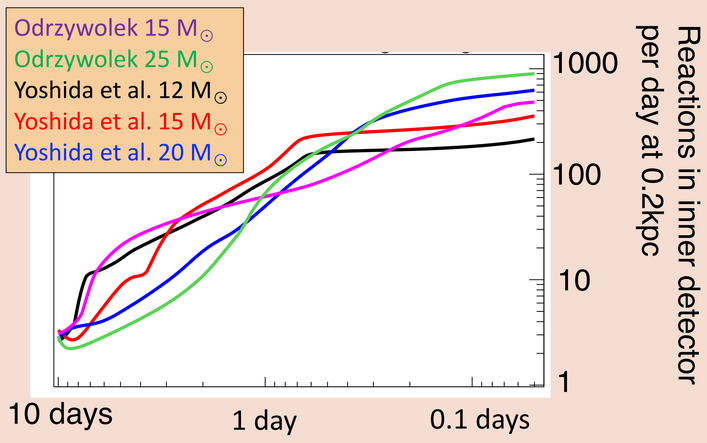


Schematic inverse beta decay with neutron capture. Charged particles produce Cherenkov light which is detected by PMTs. Gamma rays scatter electrons which produce Cherenkov light.

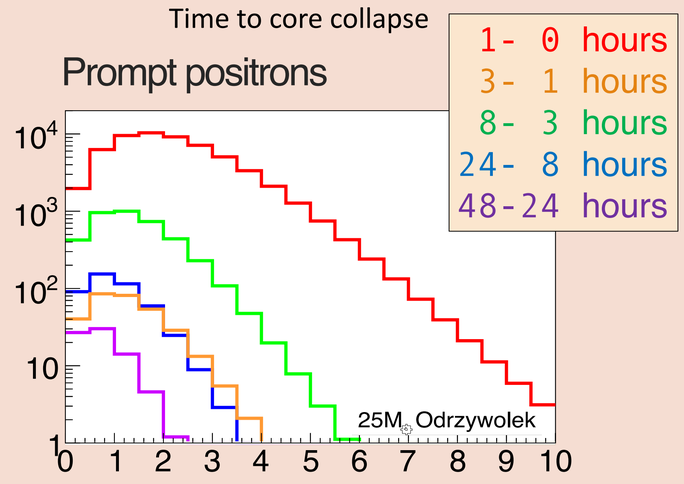
Pre-Supernova Neutrinos

- Massive star prior to core collapse
- Star running out of H and He
- Contracts and gets hotter
- Heavier nuclei are fused
- Higher temperature leads to rapid increase to production of neutrinos and antineutrinos [2]
- At SK-Gd, detection efficiency for antineutrinos will be increased
- **Pre SN warning for nearby stars**
- **Never before seen astrophysical object, not visible to EM astronomy!**

Rapid increase in IBD event rate at SK-Gd at 200 parsec



Prompt positrons

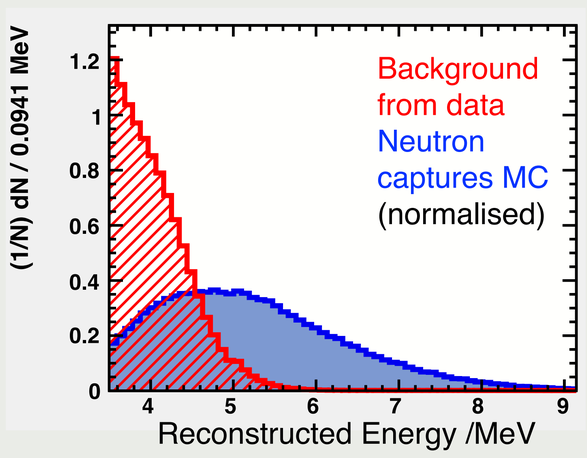


Positrons will only be detected in the final hours before collapse, as SK is not efficient below 3 MeV. Detection will be primarily neutron captures

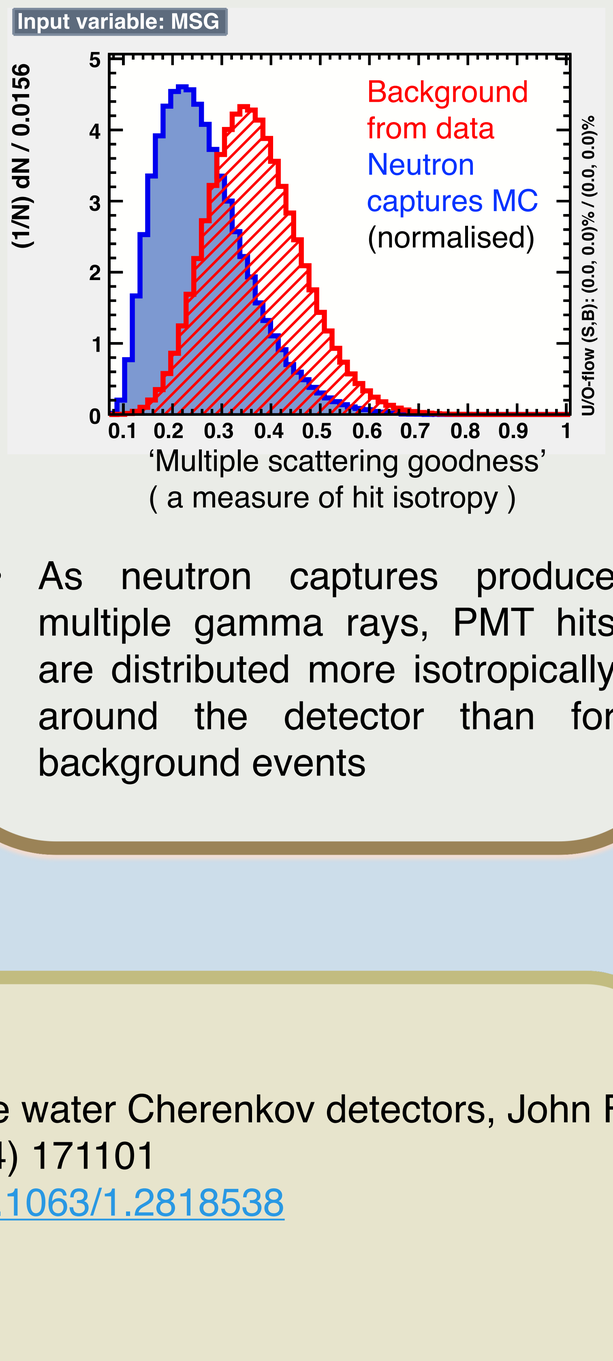
Data from [3] and [4]

Detecting Neutron Captures

- Neutron capture gammas are studied using MC [5]
- Background is modelled using real data taken in SK



- Low energy background at SK is dominated by radioactivity from Ra/U/Th chain contamination of water and PMT covers



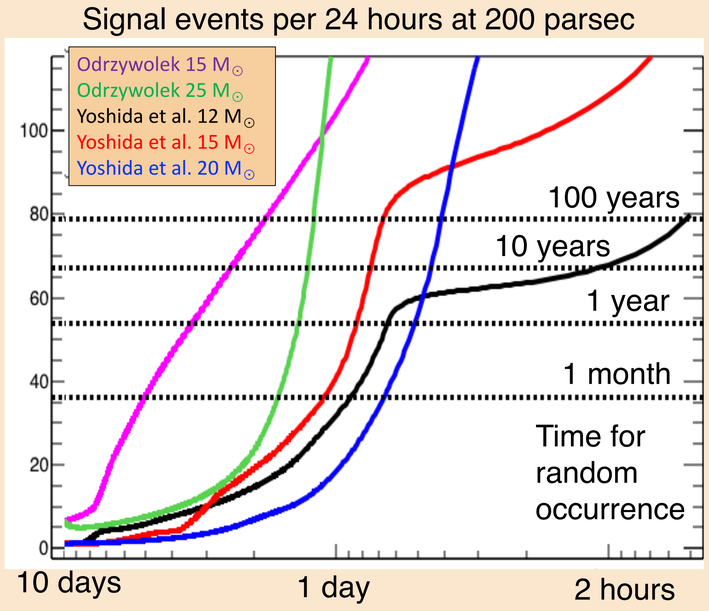
- As neutron captures produce multiple gamma rays, PMT hits are distributed more isotropically around the detector than for background events

How much warning?

Assume

- 24 hour moving window
- neutron singles only
- Assumed 338 BG per day, 37% signal efficiency in ID
- ½ day warning for all models at 1 per year false rate
- 20 $M_\odot$ at 200pc is a reasonable assumption for Betelgeuse

Signal events per 24 hours at 200 parsec



References

[1] GADZOOKS! Anti-neutrino spectroscopy with large water Cherenkov detectors, John F. Beacom and Mark R. Vagins, Phys.Rev.Lett. 93 (2004) 171101
[2] Odrzywolek et al. http://aip.scitation.org/doi/pdf/10.1063/1.2818538
[3] Odrzywolek http://th.if.uj.edu.pl/~odrzywolek/
[4] T. Yoshida et al. arXiv:1606.04915v2
[5] Gd neutron capture gamma cascade model
http://neutrino.phys.ksu.edu/~GLG4sim/Gd.html