HALO

(Helium And Lead Observatory)

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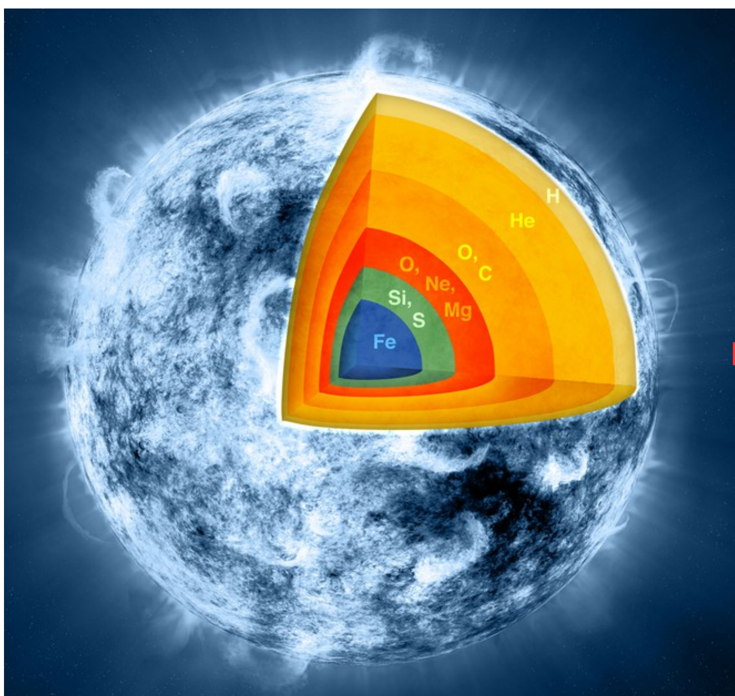
SNOLAB

Laurentian University
Université Laurentienne

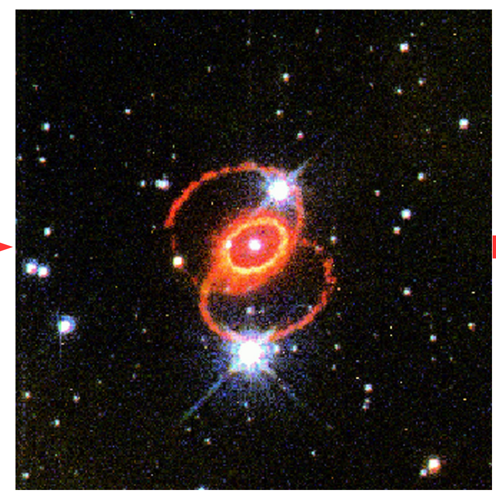
HALO

Supernovae

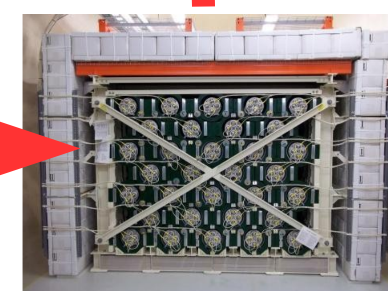
- When the inert iron core of a star reaches 1.4 solar masses, it collapses
- 99% of the released energy is in the form of neutrinos



http://www.space.com/17075-pictures-chandra-x-ray-observatory-space-telescope.html



https://www.spacetelescope.org/images/

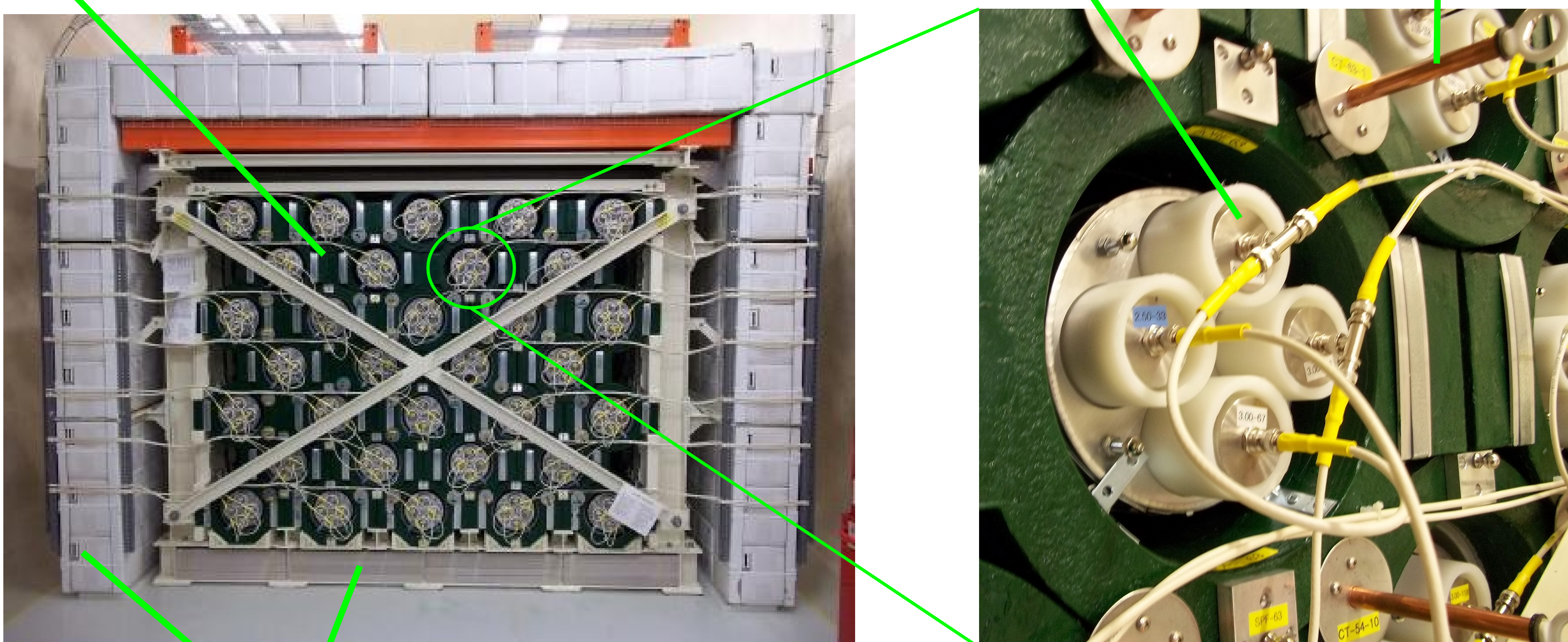


Neutrino Physics

SNEWS

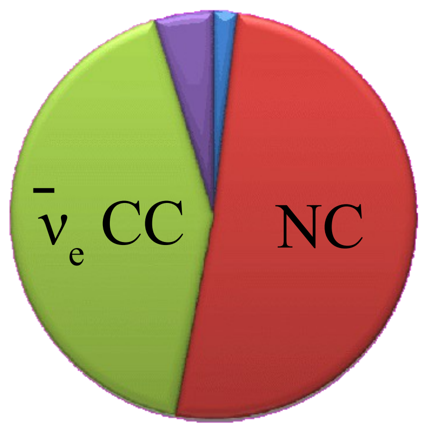
Detector

HALO consists of an array of helium-3 counters in 79 tons of lead shielded by water and plastic

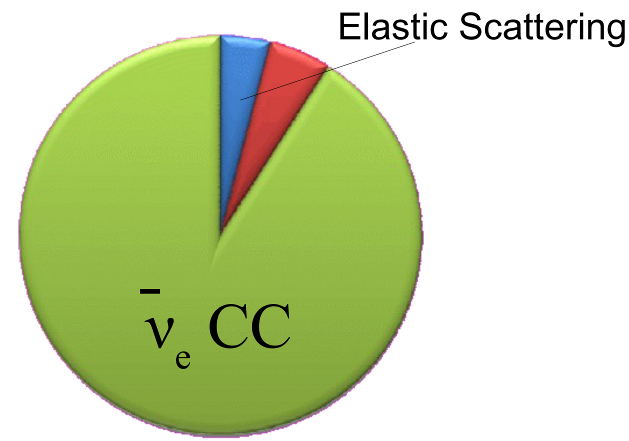


HALO has complementary flavour sensitivity to other neutrino detectors

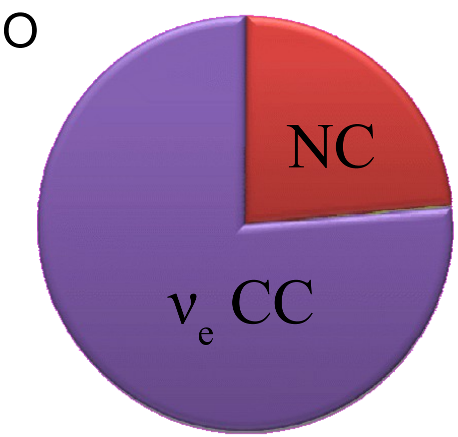
- Liquid scintillator detectors:
  - LVD
  - Borexino
  - KamLAND
  - Daya-Bay
  - Sno+



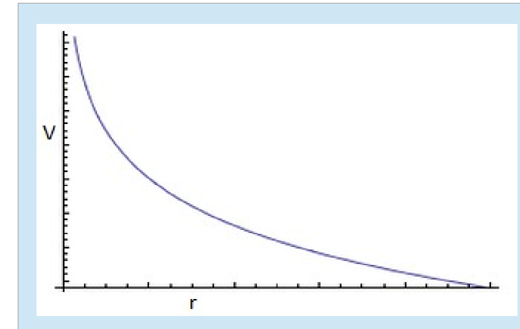
- Water cerenkov detectors:
  - IceCube
  - Super-K

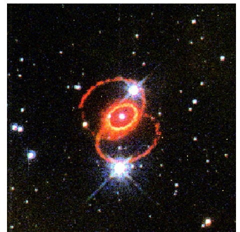


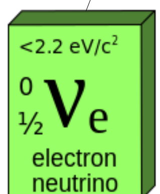
- Lead detector:
  - HALO



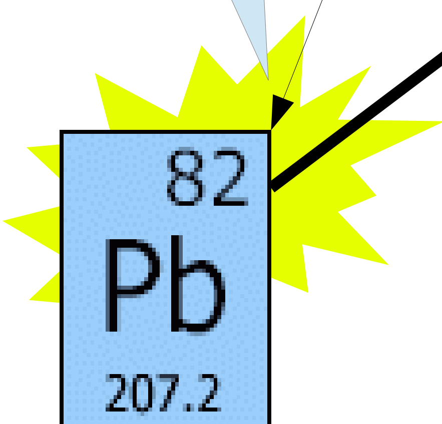
Neutrino Detection

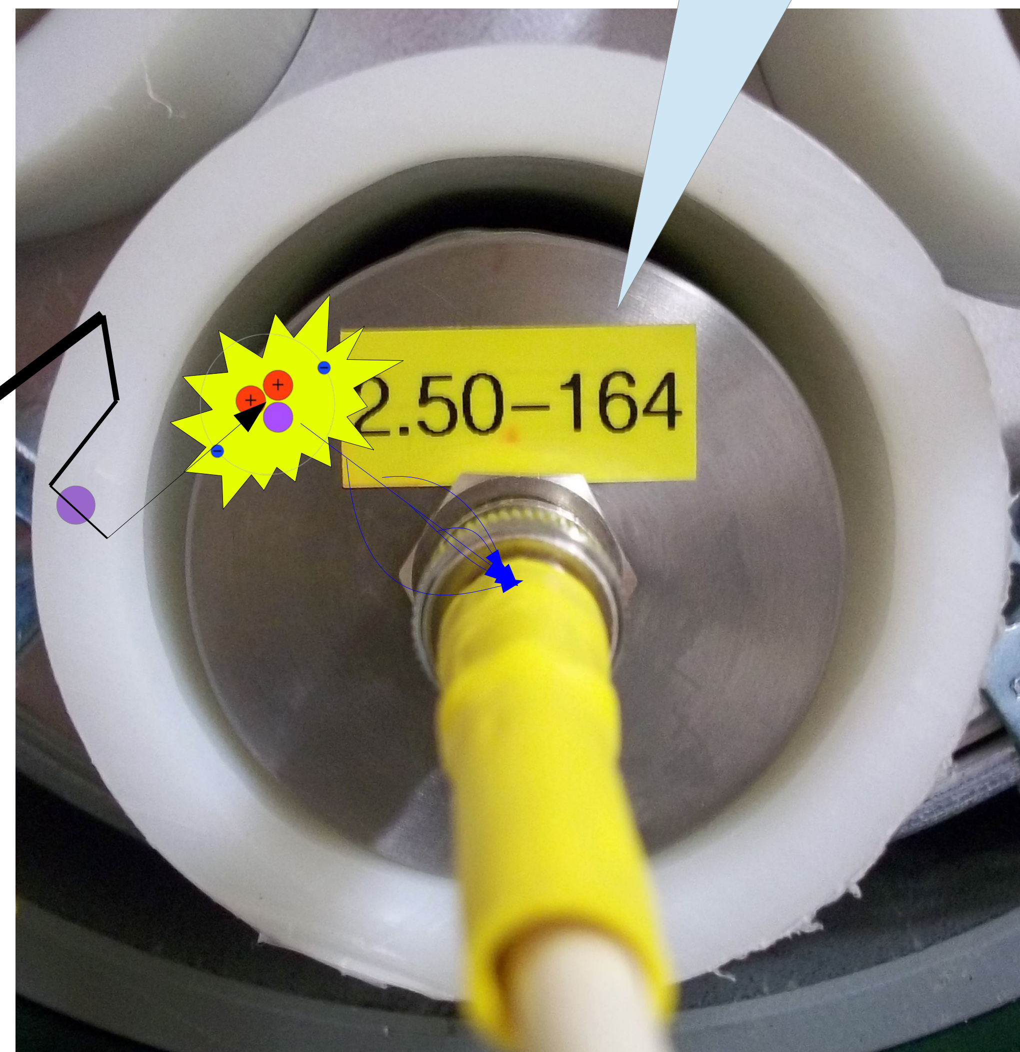






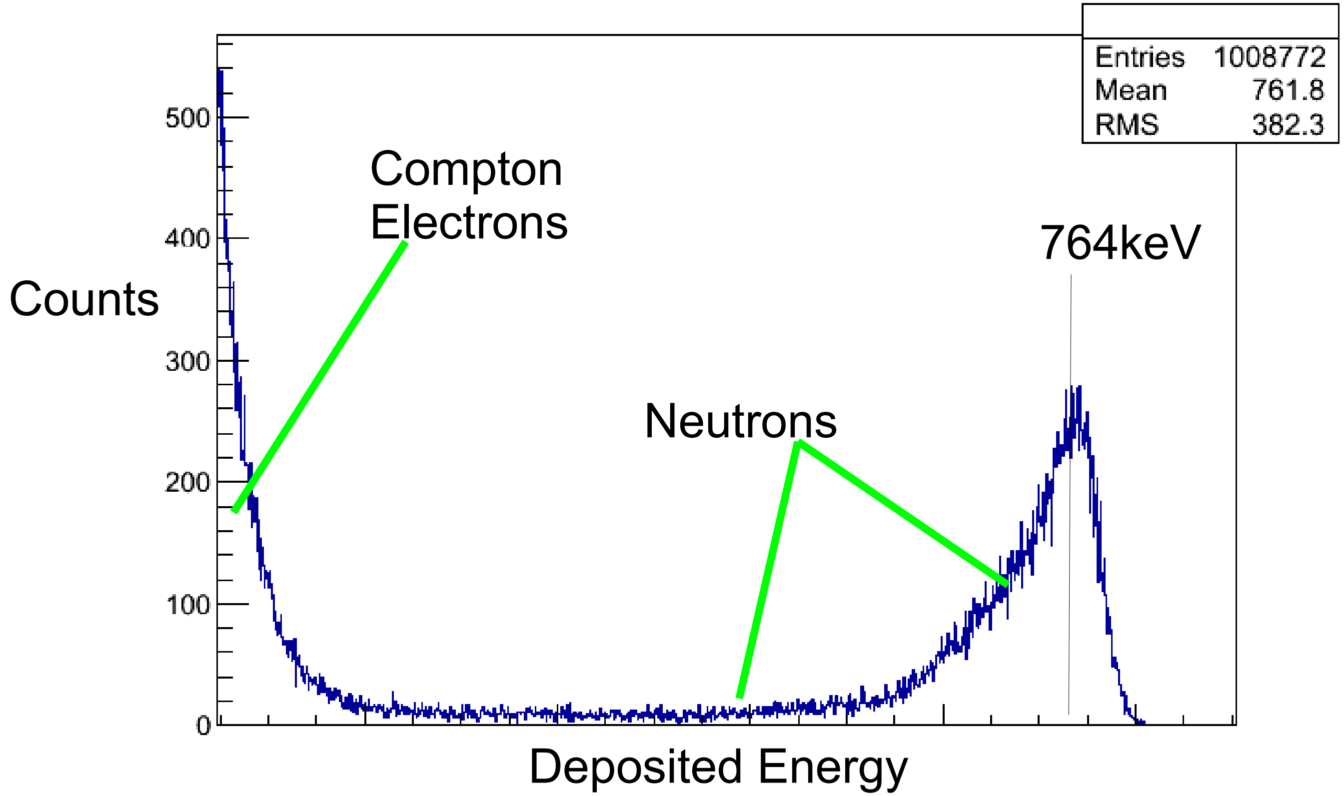
$$\nu_e + Pb \rightarrow e + Bi*$$
$$Bi* \rightarrow Bi + \gamma + n$$





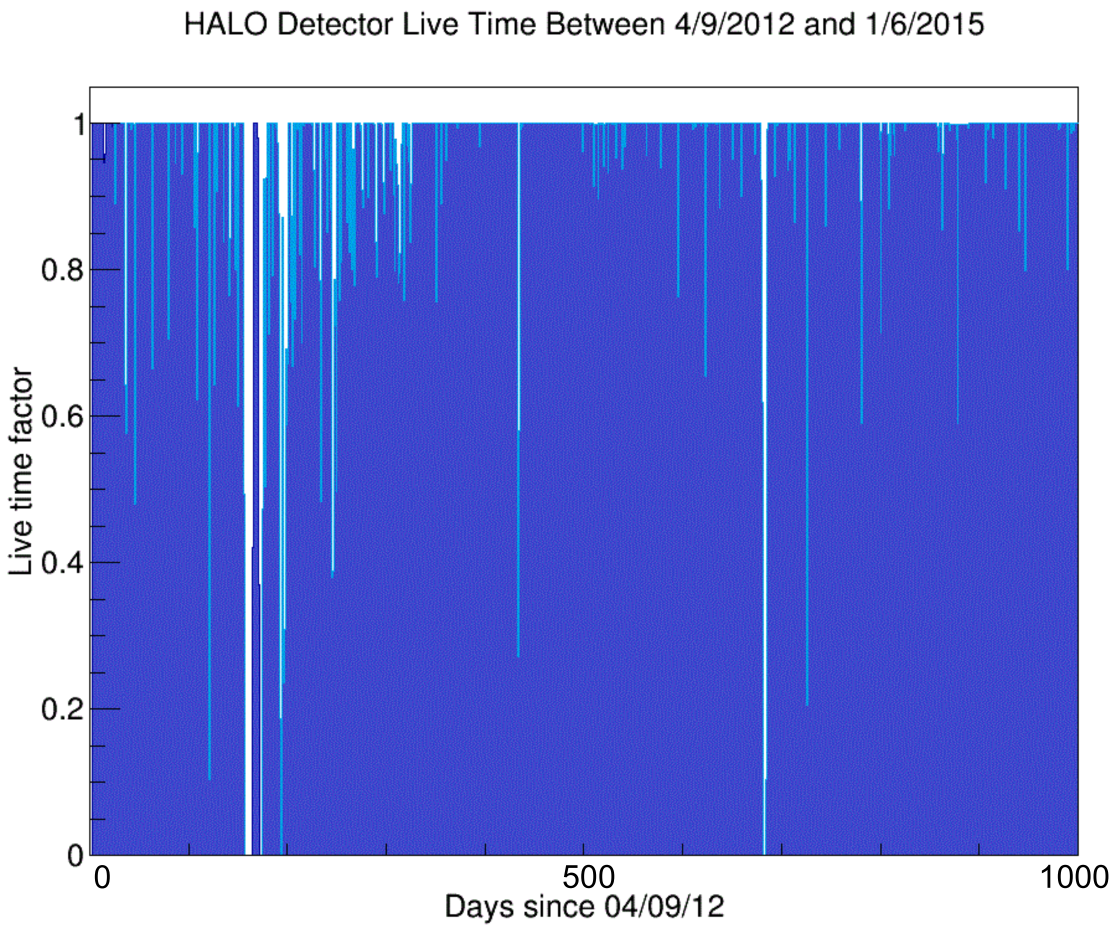
Neutrons can easily be distinguished from gamma rays

- Gamma rays only deposit small amounts of energy in the He3 counters
- Neutron captures deposit 764keV: $n + {}^{3}He \rightarrow p + t$
- Some of this energy can escape detection if the capture is very close to the wall of the counter

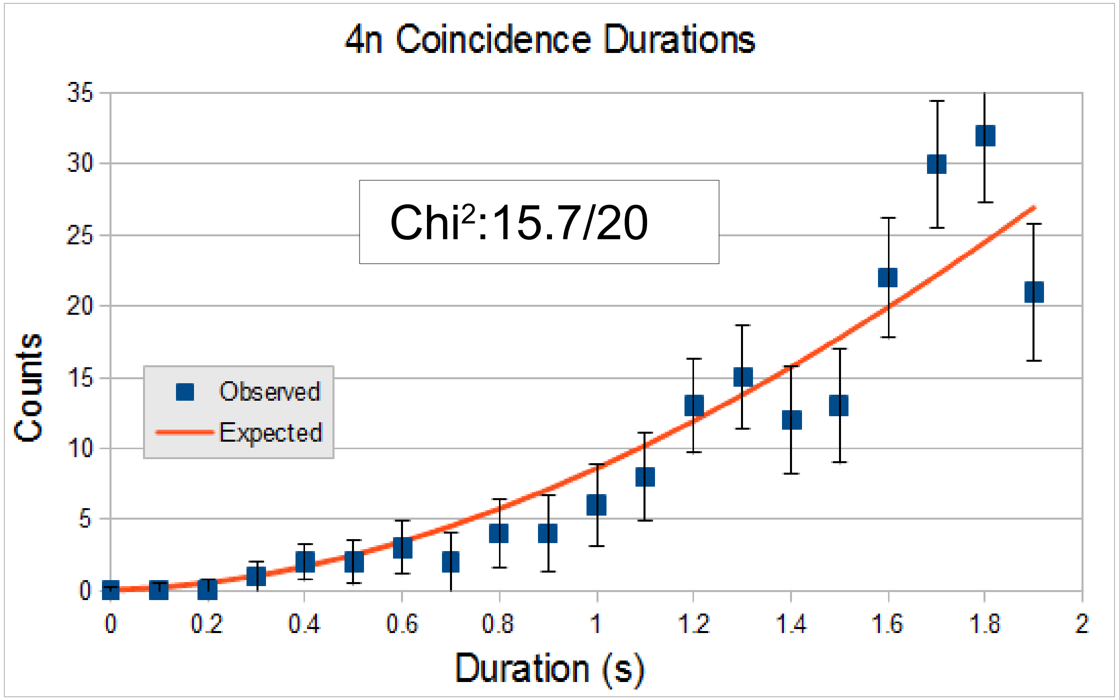


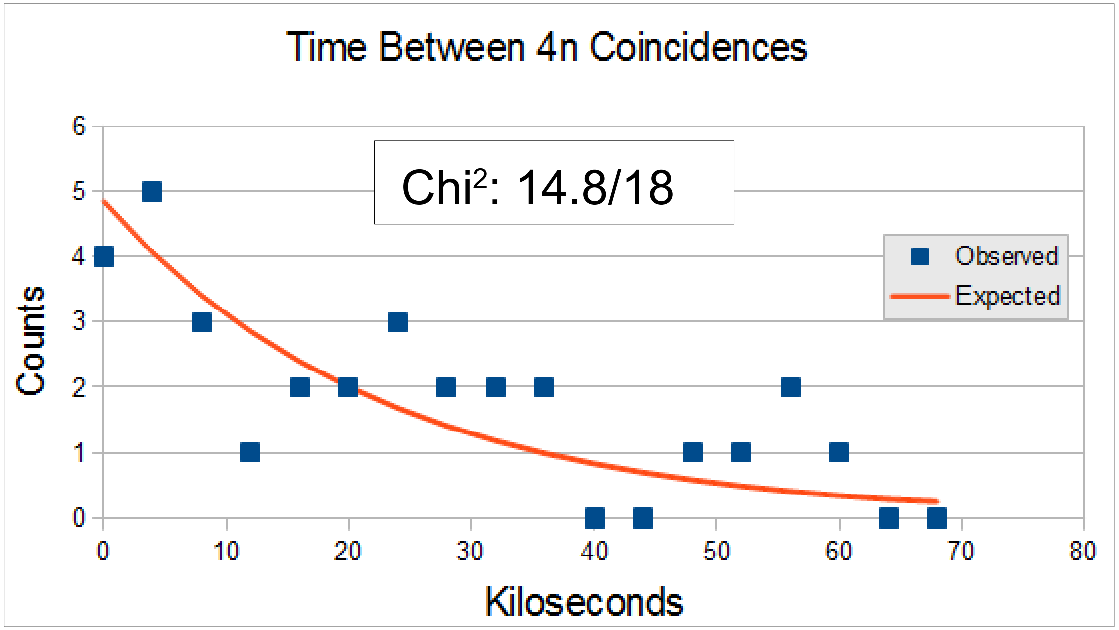
HALO has been consistently taking data

- 95% duty factor since September 2012
- Live time factor will remain high now that almost all components are installed.
- Small intermittent interruptions may continue due to power shutdowns but they will get shorter once shutdown and start-up of halo is automated.



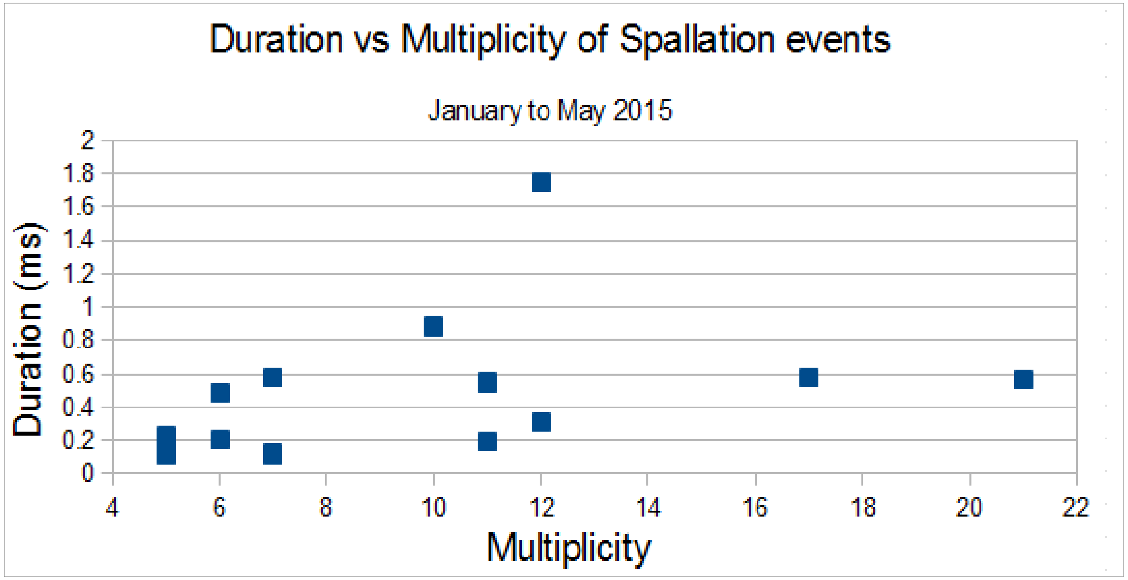
HALO's neutron coincidences have been behaving as expected

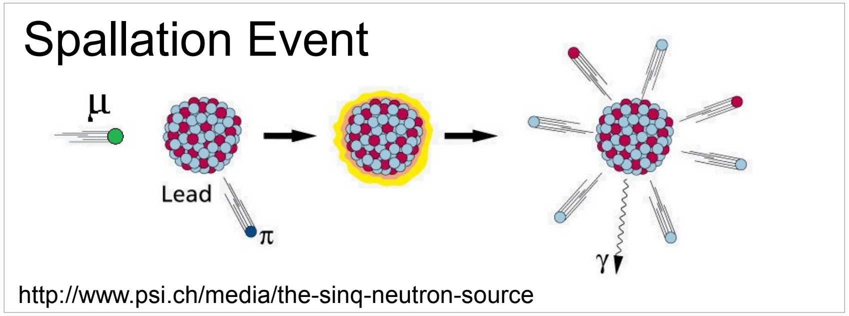


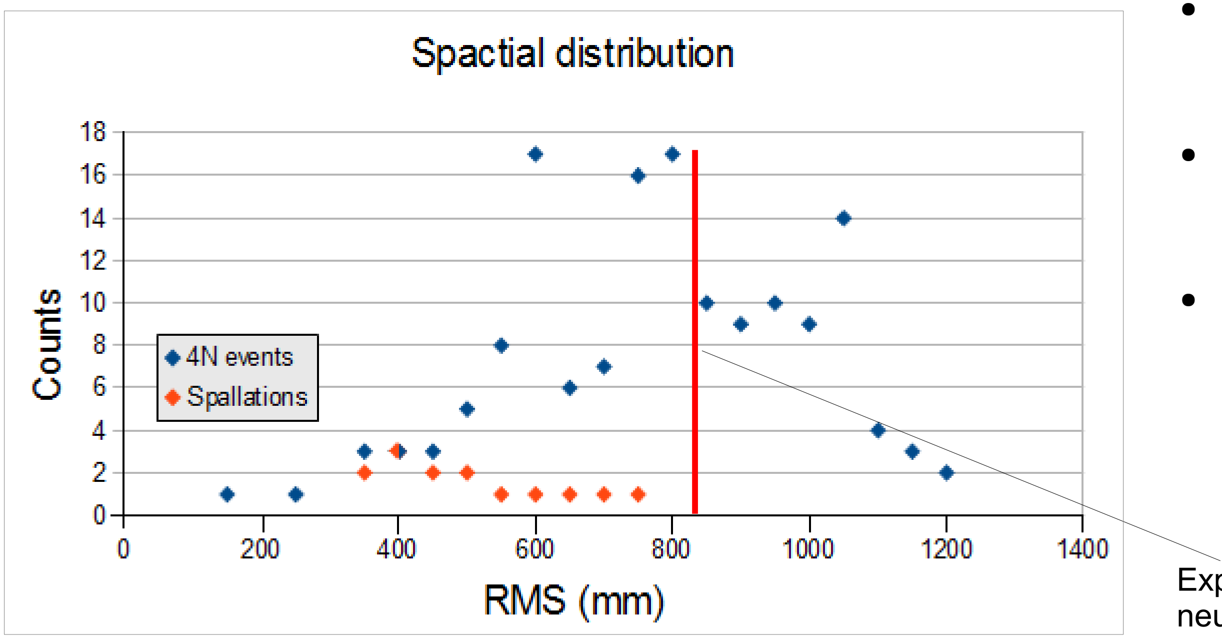


- Coincidence trigger threshold: 4 non-gamma events within 2 seconds
- Neutron background could come from the lab walls (single neutrons) or uranium decay inside the detector (some multiplicities > 1)
- After cutting out gamma events, HALO counts 6739 events per day → Expect 3.65 random coincidences per day from single-n sources.
- Found 189 over 54.4 days: Expected 198.6 +- 14.1
- This confirms that uranium spontaneous fissions are not a problem for the supernova trigger.

Spallation events have been behaving as expected



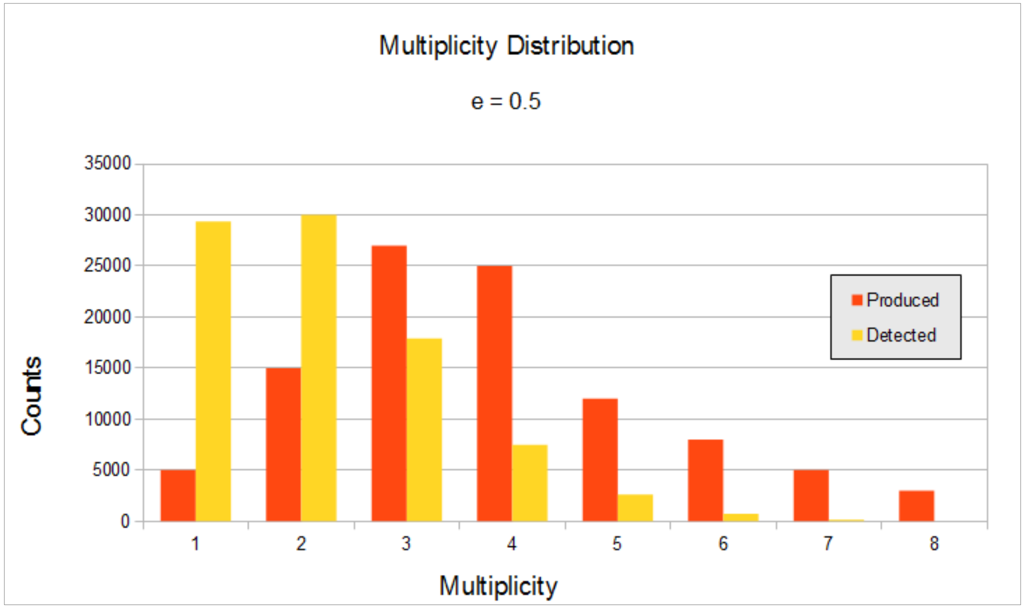


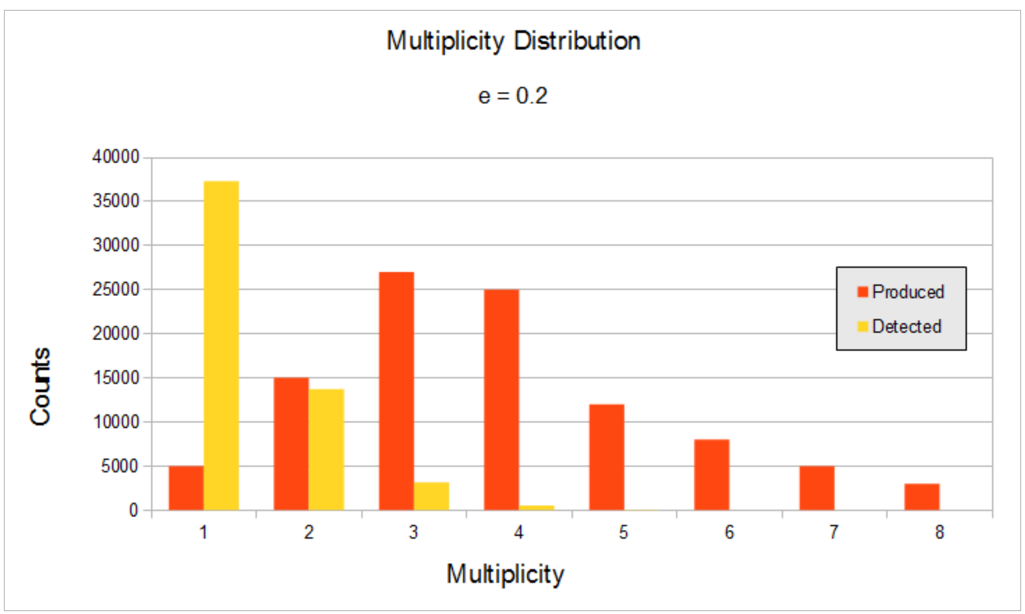


Expected RMS for homogenous neutrons: 830mm

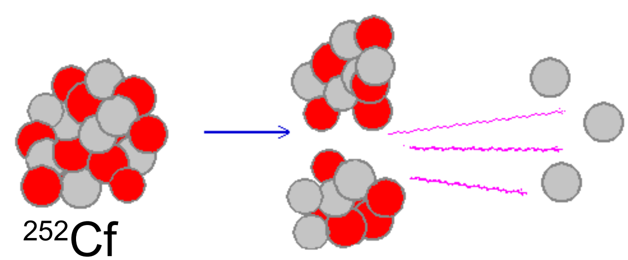
- 14 spallation events in 2015: 1 per 10 days
- Spallation events consistently end very quickly
- The spread of counts in the detector is more closely grouped than other sets of captured neutrons

^{252}Cf can precisely measure the neutron capture efficiency of HALO

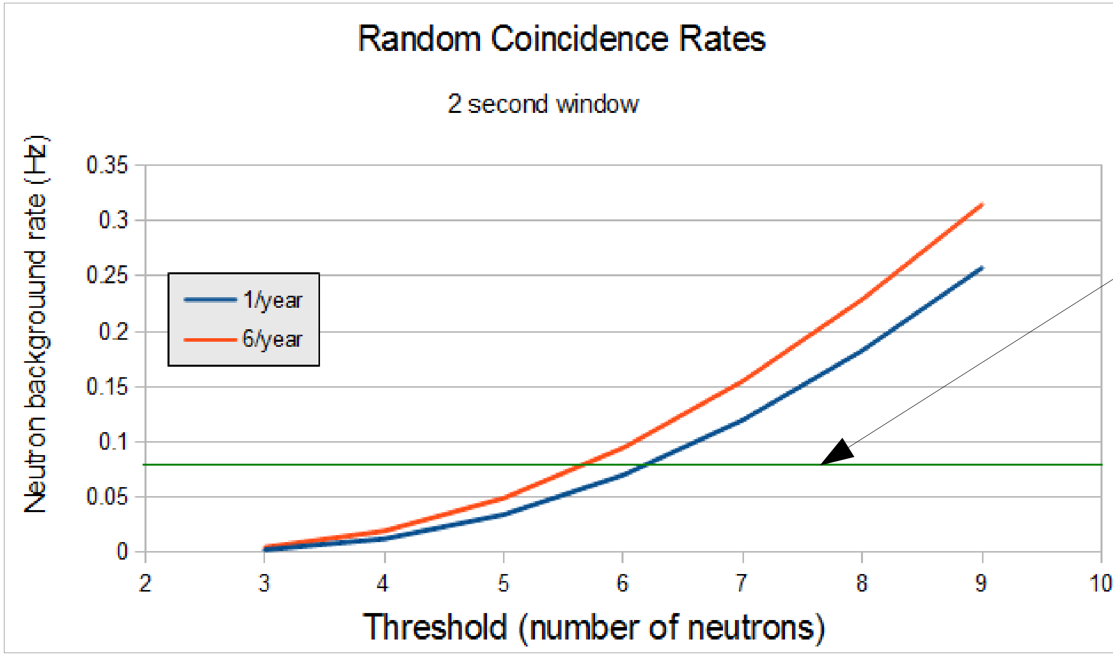




- Californium gives off bursts of neutrons with multiplicities up to 8
- The detected shape of the distribution measures the neutron capture efficiency
- The calibration will be completed this summer



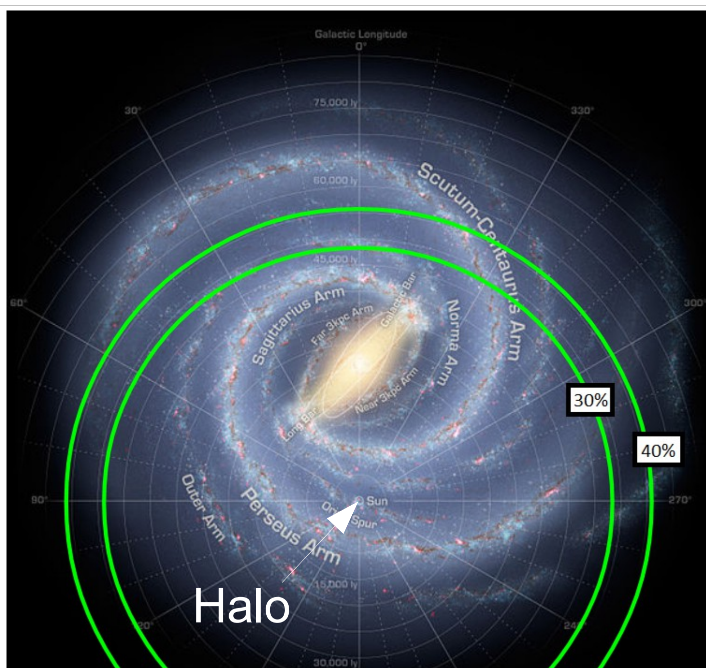
HALO covers most of the Milky Way



Current neutron rate: 6350 +- 10 per day (0.0735n/s)

Setting 6 neutrons in 2 seconds as a supernova candidate gives 1.17 random triggers per year

Neutron rate will be lowered when front shielding is put in place.



- Detection range depends on threshold and detection efficiency
- Detection range with capture efficiency 0.3, threshold of 6 neutrons: 14.7 kpc (48.1 kly)
- Detection range with capture efficiency 0.4, threshold of 6 neutrons: 16.9 kpc (55.1 kly)

We are currently considering an opportunity to create a kiloton scale lead supernova detector! Contact cjv@snolab.ca for details.

- http://www.spitzer.caltech.edu/images/1925-ssc2008-10b-A-Roadmap-to-the-Milky-Way-Annotated-

The HALO Collaboration

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