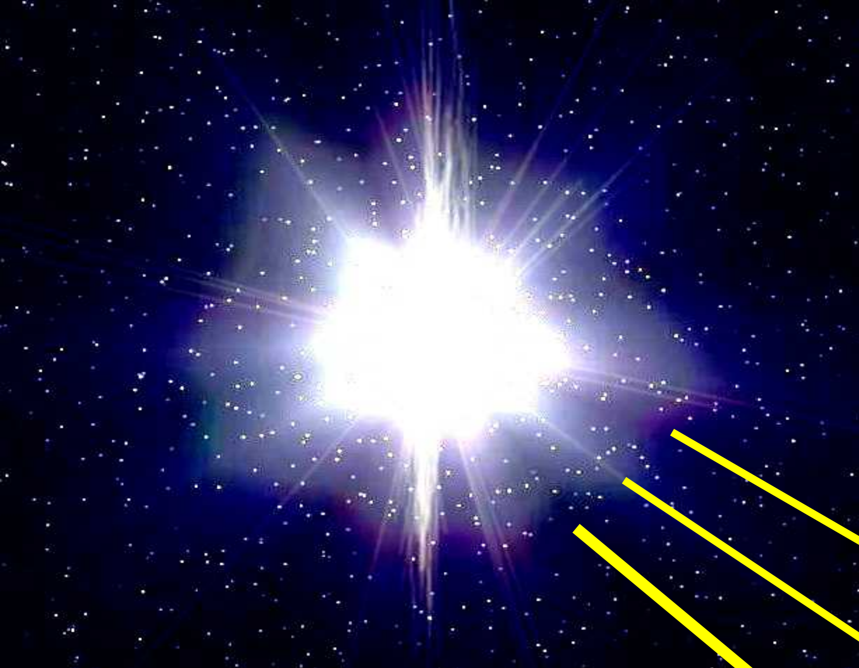
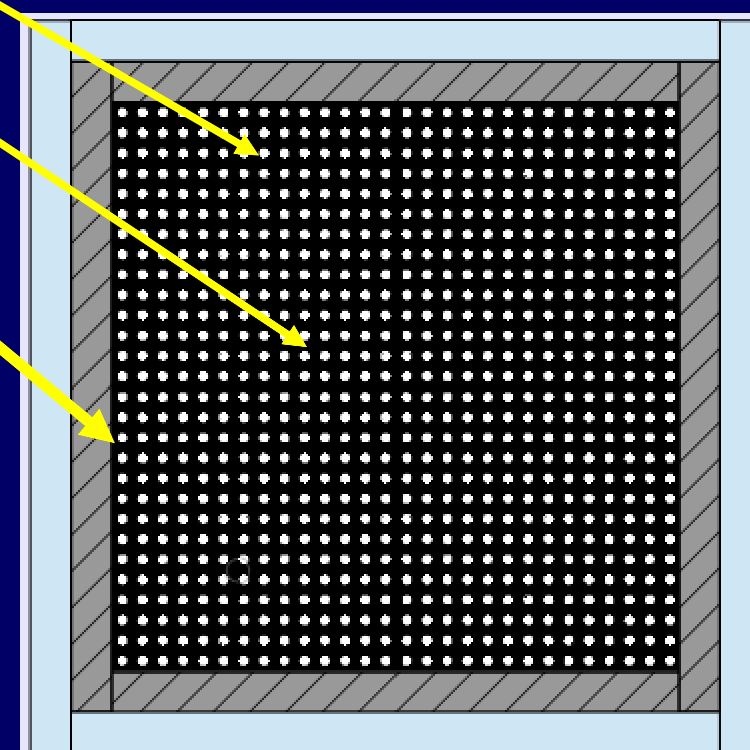


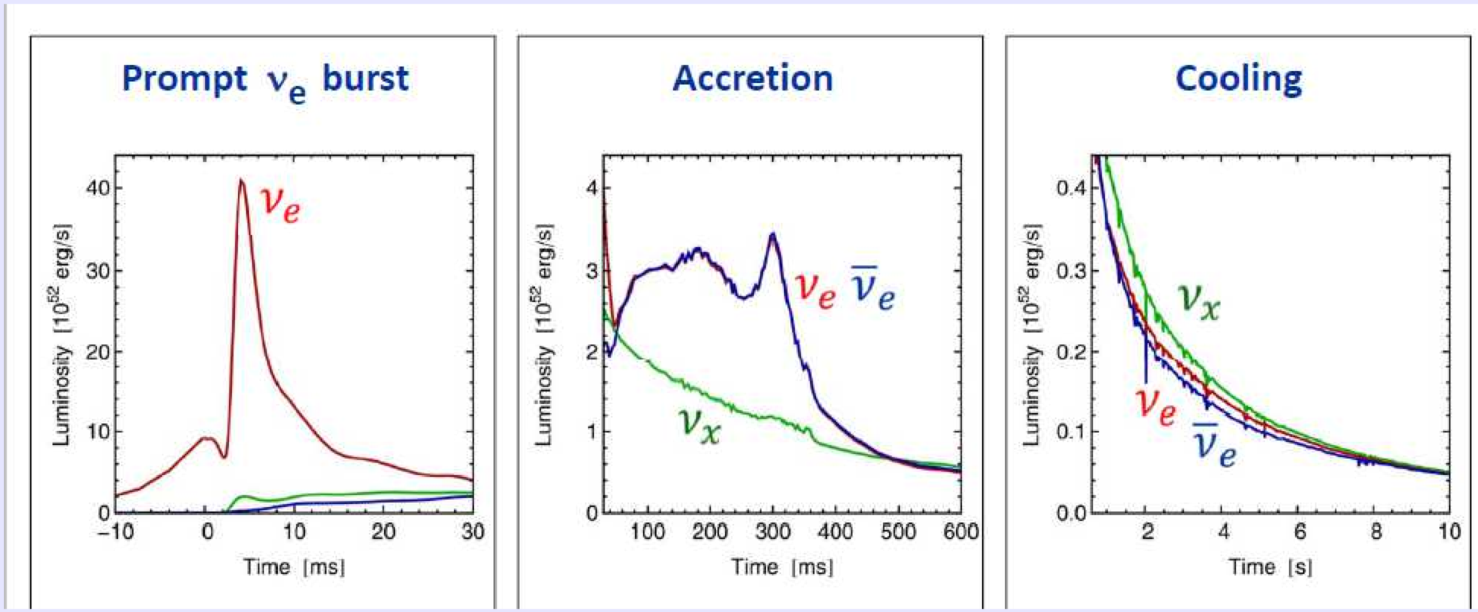
HALO-1kT



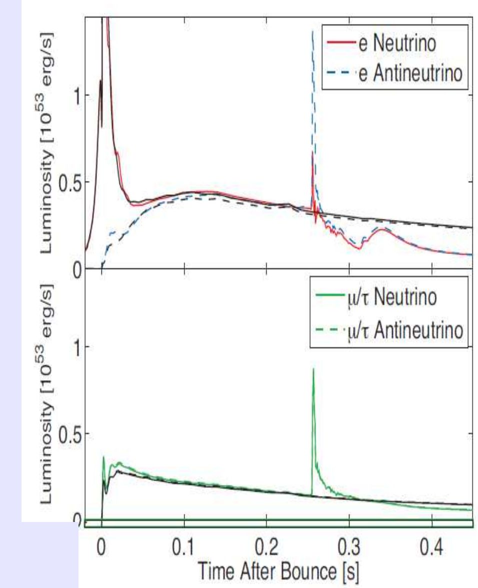
Stanley Yen, TRIUMF

for the HALO-1kT collaboration

Each stage of a supernova emits a different neutrino flavor mixture, according to current models.



from G. Raffelt, Shanghai Conference, 2013.



adapted from Sagert et al. arXiv:0902.2084 [astro-ph.HE]

Essential to observe each flavor separately for a complete picture, but Water Cerenkov and organic scintillation detectors are sensitive mostly to anti-ν_e via IBD on protons.

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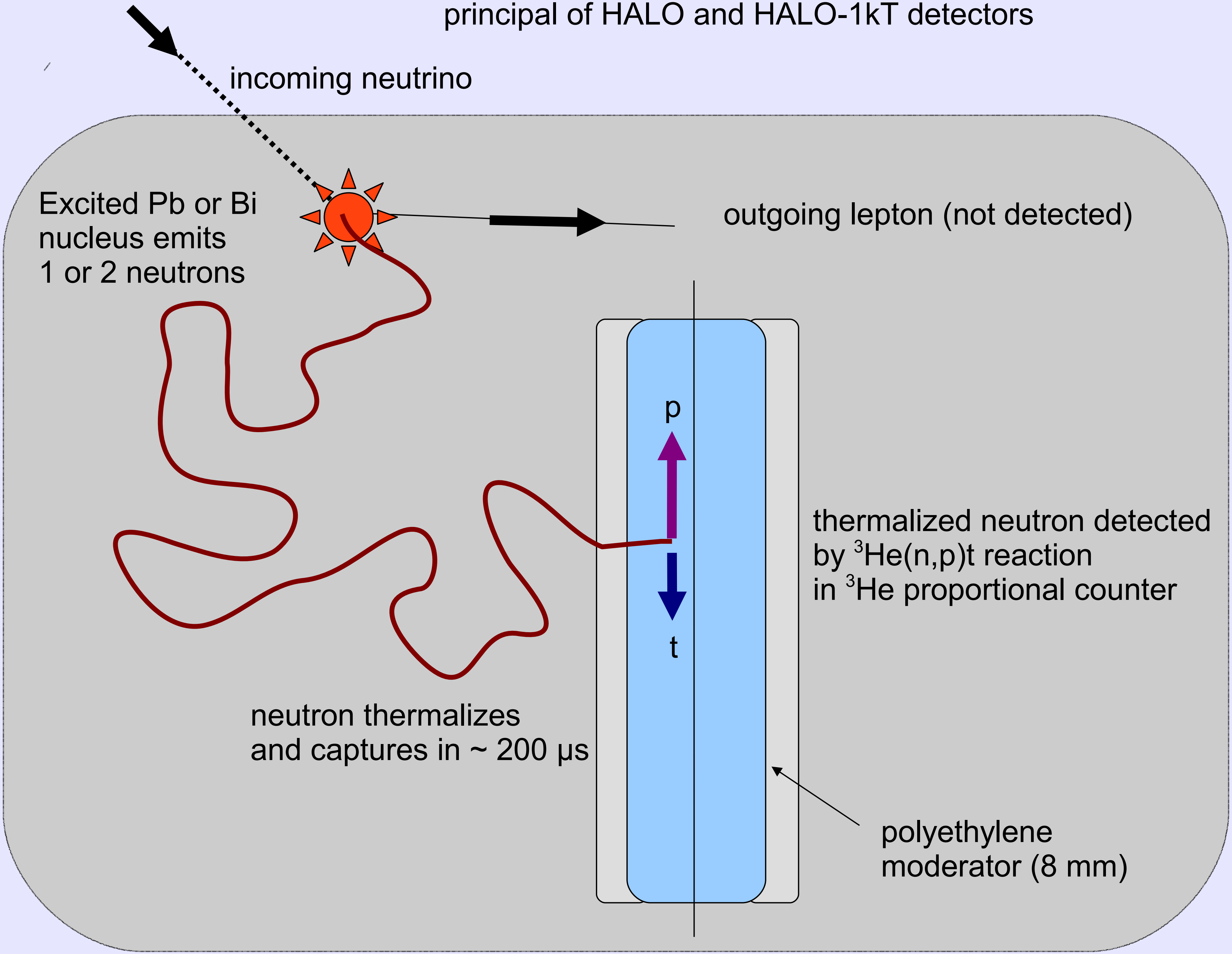
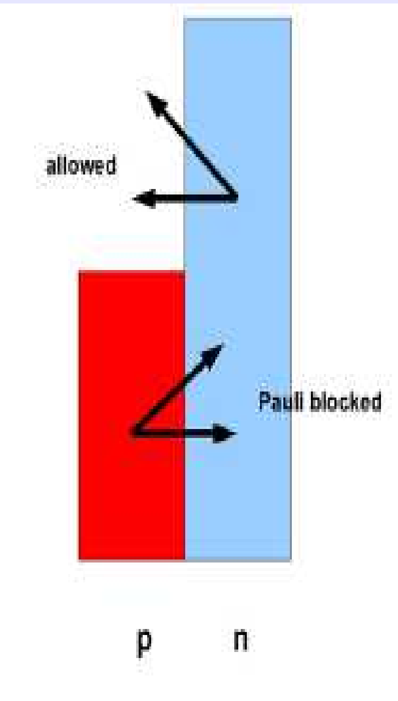
A lead detector is primarily sensitive to ν_e , thus flavor-complementary to other types.

principal of HALO and HALO-1kT detectors

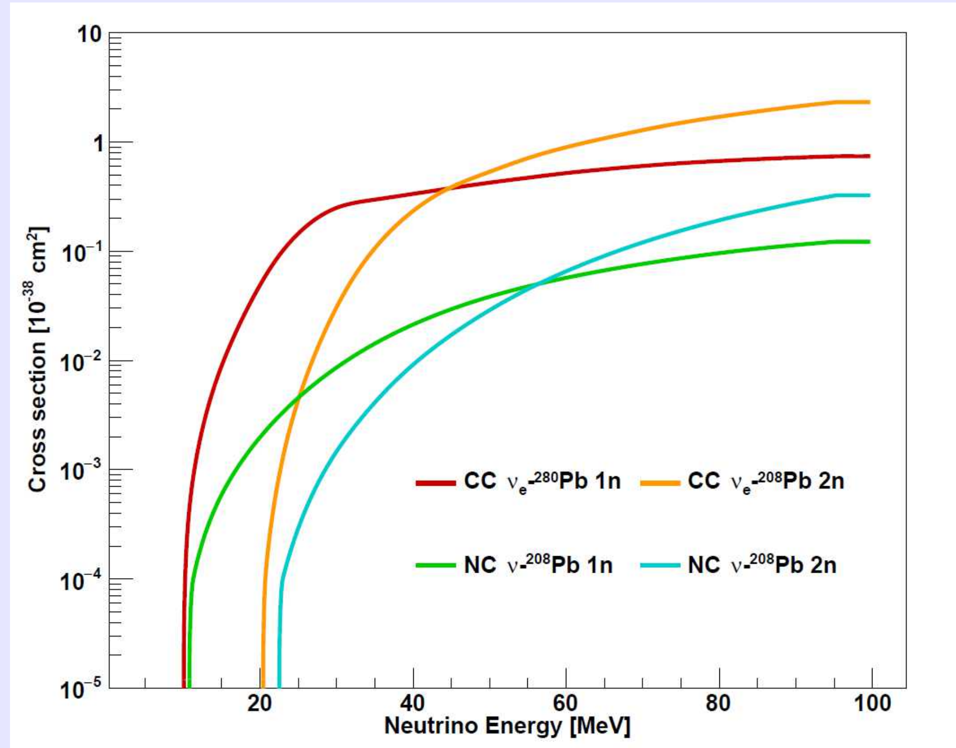


Features of Pb as neutrino detector:

1. Neutron excess blocks $p \rightarrow n$ nuclear transitions, favors $\nu_e + n \rightarrow e^- + p$



2. Large Z of Pb nucleus pulls in wavefunction of outgoing electron, enhances CC cross sec.

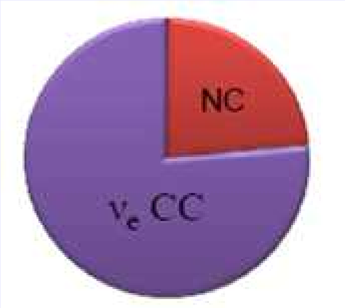


3. Ratio of 2-n to 1-n emission gives a measure of average neutrino energy

4. σ a rapid function of E, sensitive to enhancement of high E tail of ν_e

Flavour Sensitivities

Water Cerenkov

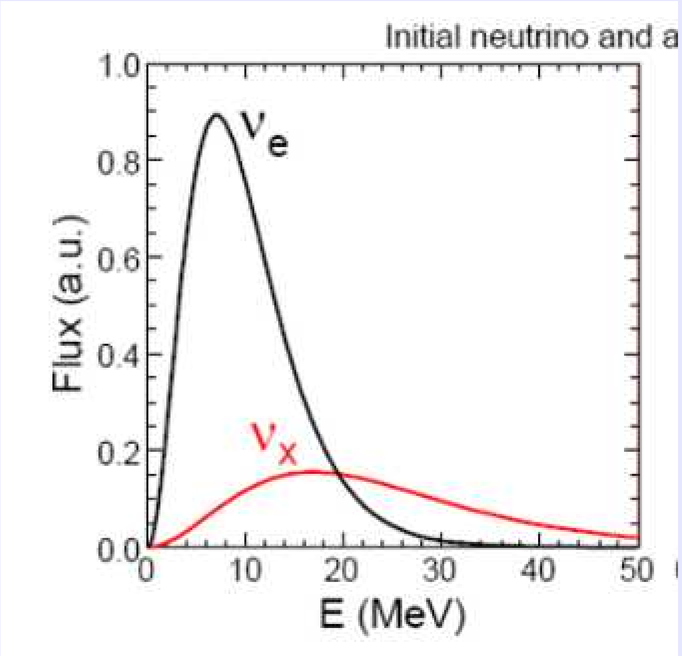


Lead

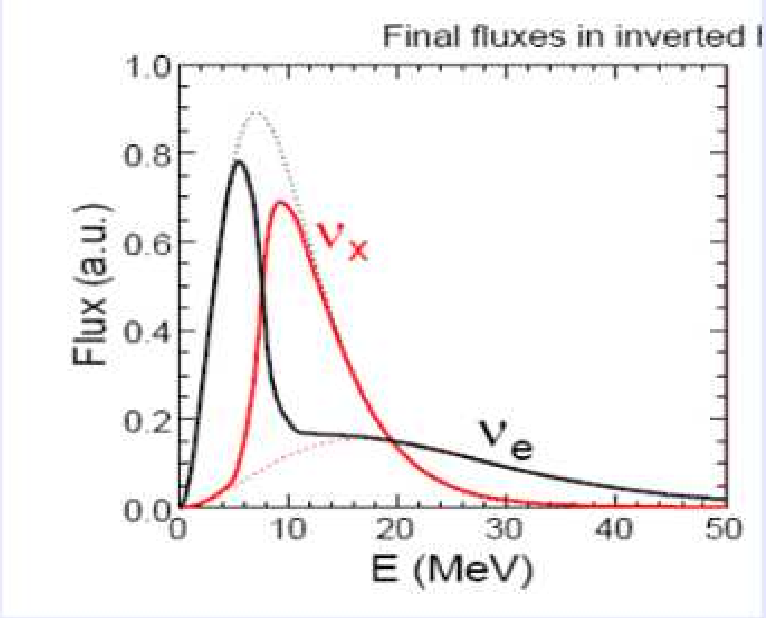
Complementarity

In general, we may not know the distance to a supernova, so the absolute number of ν_e or anti- ν_e events may not be meaningful, but the <u>ratio</u> of ν_e vs anti- ν_e events gives an indication of the relative energies of ν_e vs anti- ν_e

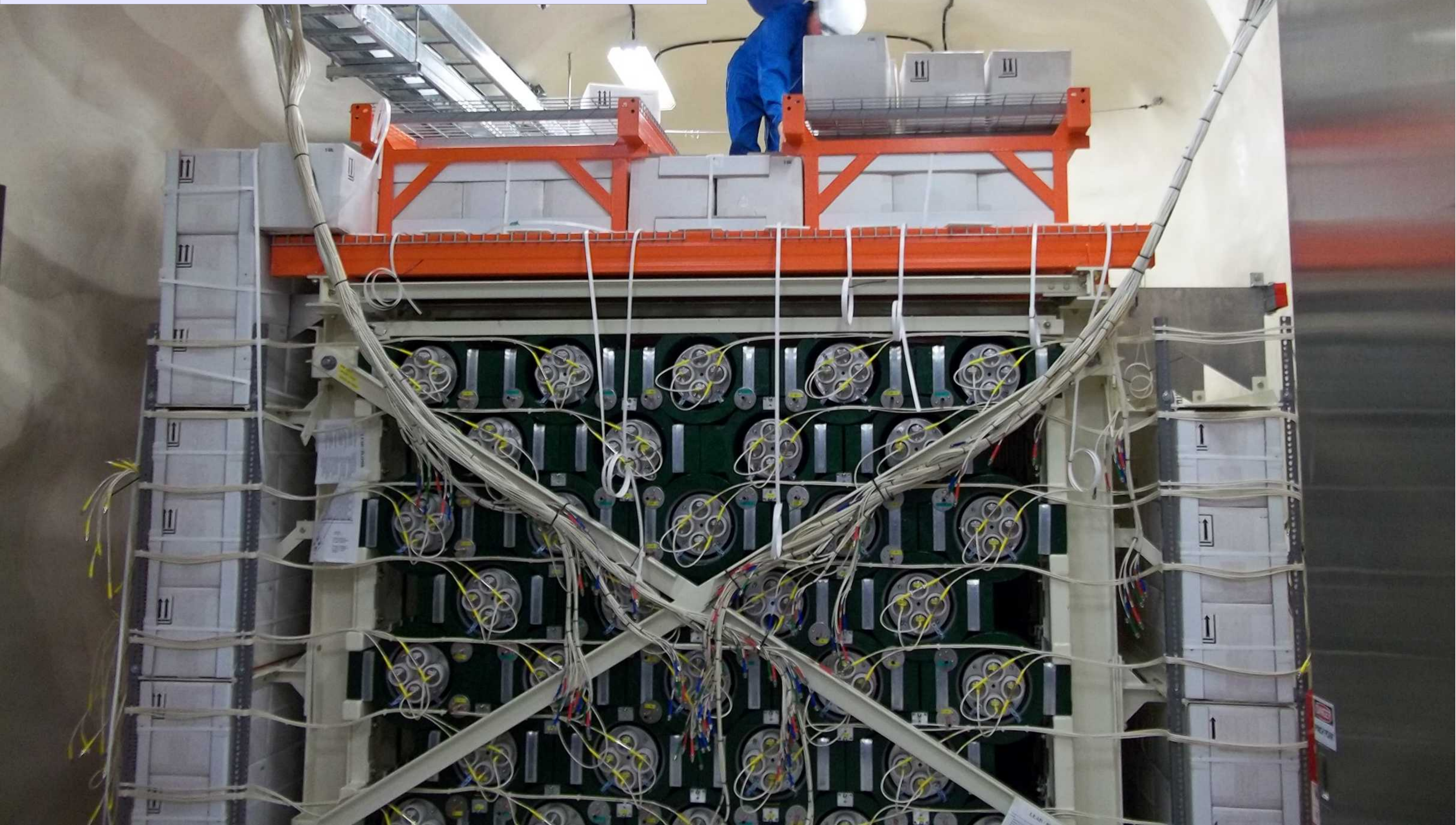
e.g. In the presence of collective ν-ν interactions,
flavor-swapping causes the ν_e spectrum becomes hotter, and
the number of events in a ν_e –sensitive detector medium like Pb Is enhanced,
relative to the number in an anti-ν_e detector.



flavor swapping



HALO @ SNOLAB
The first supernova neutrino detector with primary sensitivity to ν_e , a “Detector of opportunity” assembled using the ^{3}He neutron counters from SNO and 79 tonnes of surplus lead



HALO-1 in SNOLAB is complete, has been taking data since 2012,
a member of SNEWS since fall 2015; a well-calibrated, well-understood detector studied by inserting a Cf neutron source into the lead matrix.

But at only 79 tonnes, may detect as few as ~10 events for a supernova at the galactic centre, depending strongly on neutrino temperature and unmeasured ν-Pb cross sections.

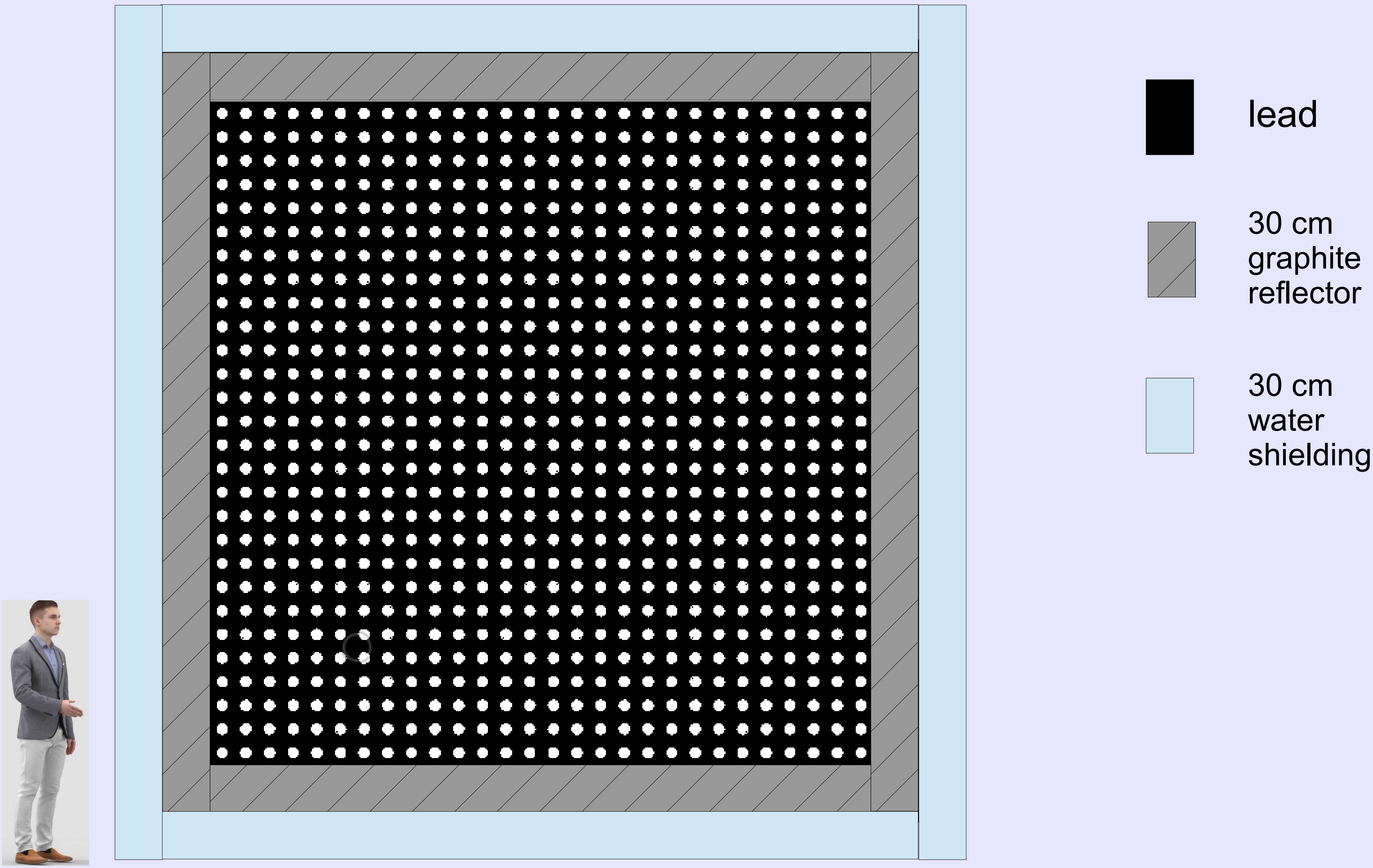
- we have plans to measure cross sections using a "mini-HALO" at SNS

The decommissioning of the OPERA experiment at the Gran Sasso lab in Italy has made available 1000+ tonnes of lead

We hope to use this to build another "detector of opportunity" in Gran Sasso, with ~12x greater mass and almost ~2x higher neutron detection efficiency than HALO-1, for a net gain of ~20x in sensitivity.

The anticipated rate of core-collapse supernovae in our galaxy is 3 ± 1 per century.
The appropriate instrument is a long-lifetime, low-maintenance, robust detector that can be built and then left to run by itself for decades .

current conceptual design:
4.3 x 4.3 x 5.5 metre volume of lead, with 28x28 cylindrical proportional counters each 5 cm diam x 5.5 m long, containing in total 10,000 litre-atm of ^3He gas, each enclosed in 8 mm of polystyrene moderator



Neutron detection efficiency ~ 53%
Expect ~200 detected events for a SN at 10 kpc

- Not enough ^{3}He neutron detectors from SNO to instrument 1 kT of lead

- Off-the-shelf commercial neutron detectors have about 60x the level of background that we can tolerate for a SNEWS trigger

- Working to mitigate this by electroplating inside walls of neutron counters with high-purity copper

- initial inquiries to US DOE to acquire 10,000 litre-atm of ^{3}He gas

- now have collaborators from Canada, USA, Italy holding bi-weekly video meetings

- working towards a scientific proposal for September 2019

HALO-1kT in the global context

Detector	Target medium	#detected	dominant sensitivity
Super-K	Water Cerenkov	8,000	anti-ν_e
Hyper-K	Water Cerenkov	110,000	anti-ν_e
ICECUBE	ICE Cerenkov	10^6	anti-ν_e
SNO+	scintillator	300	anti-ν_e
JUNO	scintillator	6000	anti-ν_e
DUNE	liquid argon	3000	ν_e
HALO-1kT	lead	~150-200	ν_e

modest statistics compared to other detectors, esp DUNE.

HALO-1kT worthwhile because it has different systematics from DUNE
Counting neutron captures on ^{3}He very different from
adding all the distributed bits of electromagnetic energy in liquid argon.

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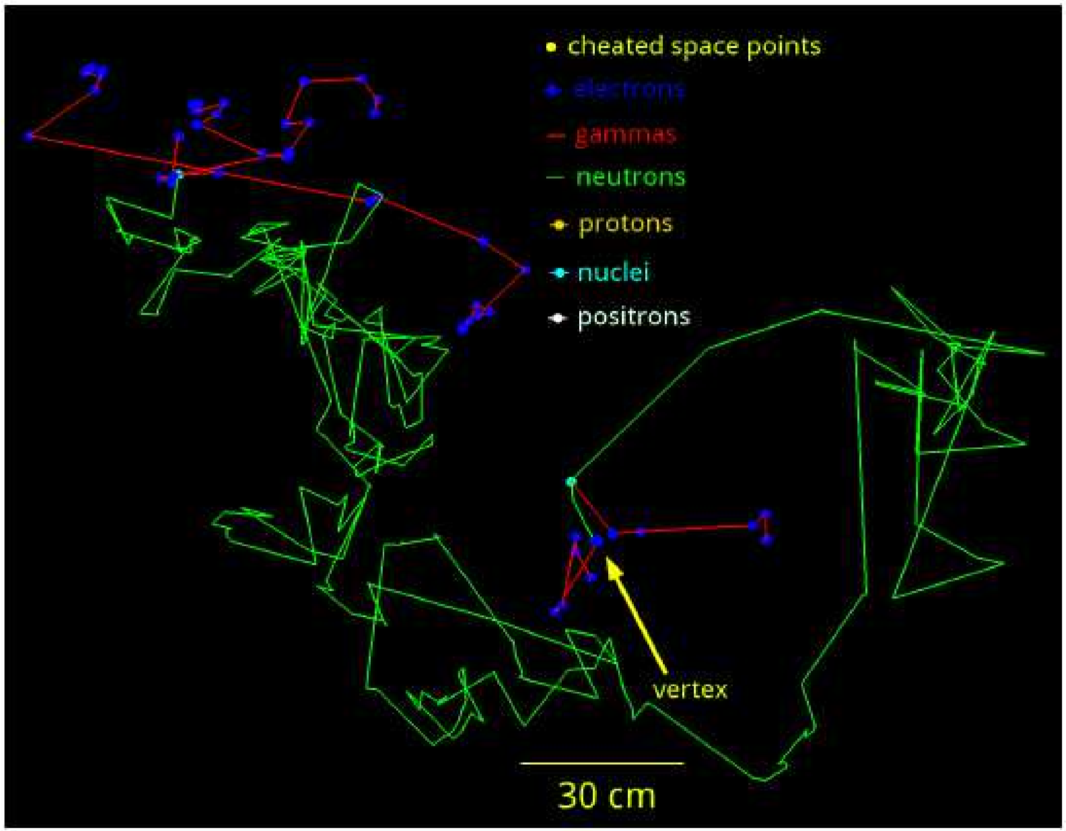

From A. Friedland,
U of Tokyo, Feb 12, 2017

HALO-1kT worthwhile because of its robustness and longevity

Current neutrino detectors are driven by programs to
measure neutrino properties (mass hierarchy, CP violation).
Will these detectors still operate after neutrino properties are measured?

Possibly NO supernova-capable neutrino detectors after the neutrino oscillation parameters are measured! A disaster for our field, which expects one SN only every 30 to 50 years.

By contrast, HALO-1kT will be robust and practically zero-maintenance;
^{3}He-filled neutron counters have mean time to failure of >800 years.
We could potentially sit there for decades or even centuries …
and observe several core collapse supernovae, and look at systematics

- explosion energy and evolution as a function of progenitor mass, angular momentum, chemical composition

- what fraction of CCSN are duds (core collapse but no explosion)?

- what fraction end as Black Holes?

- what fraction might repeat the double ν burst seen in SN1987A if one believes the Mt Blanc signal?

New collaborators welcome!

Please contact Clarence Virtue cjv@snolab.ca

Thank you!