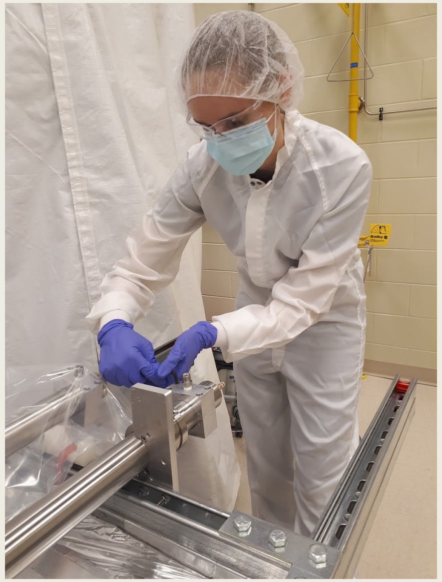
SNEWS & HALO

EIEIO
May 11, 2021
Esther Weima (She/them)



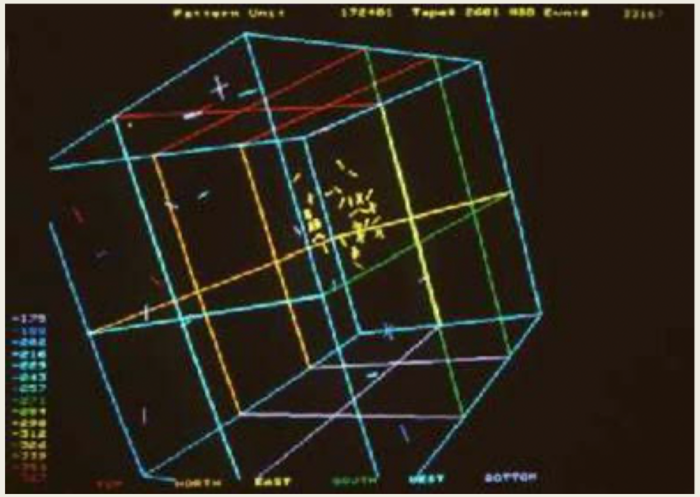
WHO AM I?

SNEWS – THE SUPERNOVA EARLY WARNING SYSTEM

TOS - The Original SNEWS

- Idea formed at Neutrino '96 and '98 by John Bahcall & members of Super-K, SNO, MACRO, and LVD
- First international SNEWS workshop in sept '98
- Wanted to do the next supernova better than SN1987A

WHY?



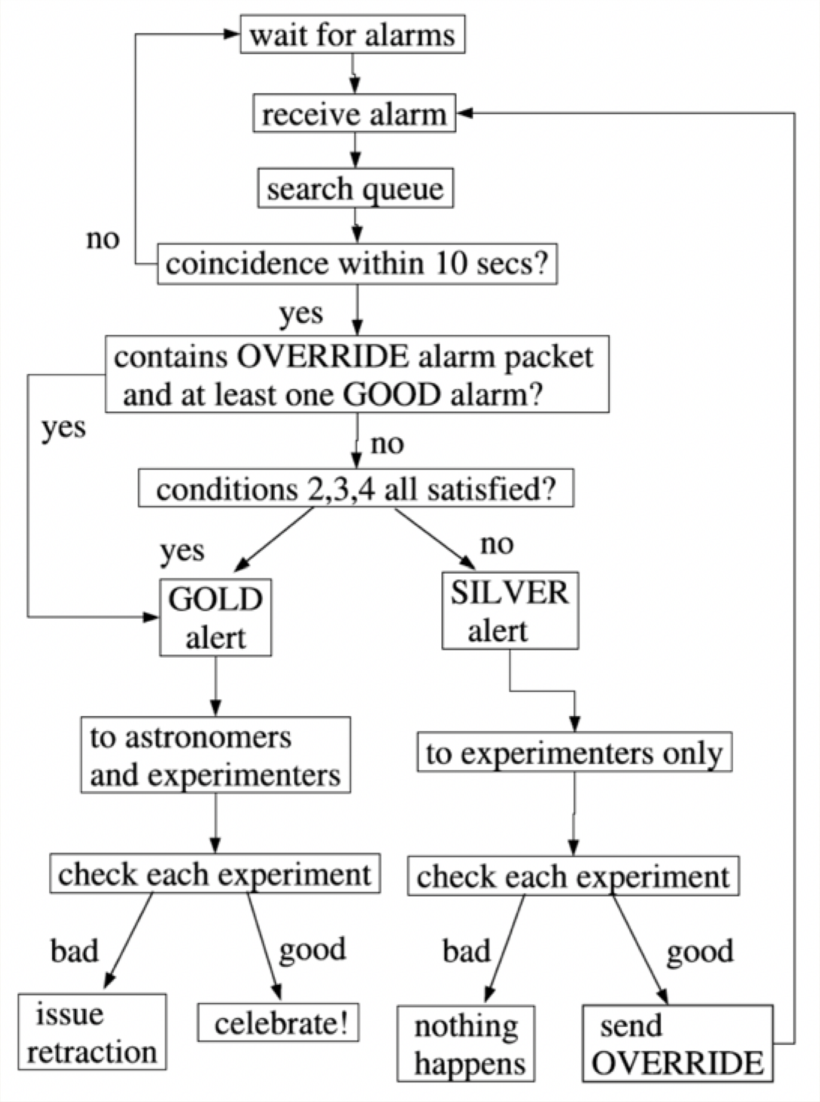
- SN1987A was observed by Ian Shelton
- The neutrino signal was later found
- The neutrinos arrived 1.5hrs before the light
- Neutrinos can provide an early warning
  - *Let astronomers know so they can point their telescopes*

The 3Ps

- Prompt
  - *Experiments send “ALARMs”*
  - *SNEWS “ALERTs” within a few min of neutrino burst*
- Pointing
  - *Important*
  - *Triangulation requires several high statistics detectors*
  - *Super-K can use anisotropic electron neutrino elastic scattering*
- Positive
  - *No false alarms*
  - *1 false / century*
  - *Not in my lifetime/not my problem*

The System

- 2 ALERTs within 10 seconds
- Automated if conditions met
  - *Not from the same lab/area*
  - *Burst history of detector less than once per week*
  - *Flagged by experiments as “good”*
- Distribution of “Confirmed” Alarms



Other pros

- Redundancy
- Spreading information widely
  - *Can sign up at snews.bnl.gov/alert*
- Governance
  - *Every experiment has members in the working group*
  - *MOU signed with participating experiments*
- Downtime coordinated through webpage accessible to working group members
- Regular meetings at Neutrino conferences

New Journal of Physics
An Institute of Physics and Deutsche Physikalische Gesellschaft Journal

SNEWS: the SuperNova Early Warning System

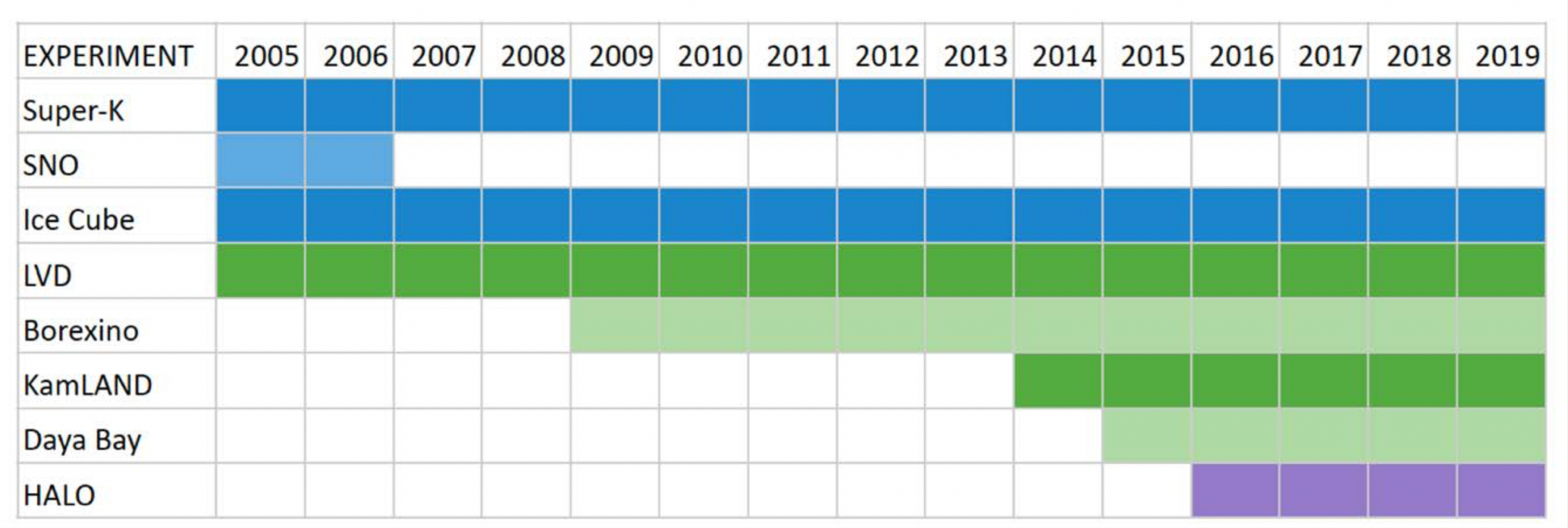
Pietro Antonioli[1], Richard Tresch Fienberg[2], Fabrice Fleurot[3], Yoshiyuki Fukuda[4], Walter Fulgione[5], Alec Habig[6], Jaret Heise[7], Arthur B McDonald[8], Corrinne Mills[9,13], Toshio Namba[10], Leif J Robinson[2], Kate Scholberg[11,14], Michael Schwendener[3], Roger W Sinnott[2], Blake Stacey[11], Yoichiro Suzuki[10], Réda Tafirout[3,15], Carlo Vigorito[5], Brett Viren[12], Clarence Virtue[3] and Antonino Zichichi[1]

CANADIANS HAVE BEEN INVOLVED FROM THE START

2004 publication

Doi:10.1088/1367-2630/6/1/114

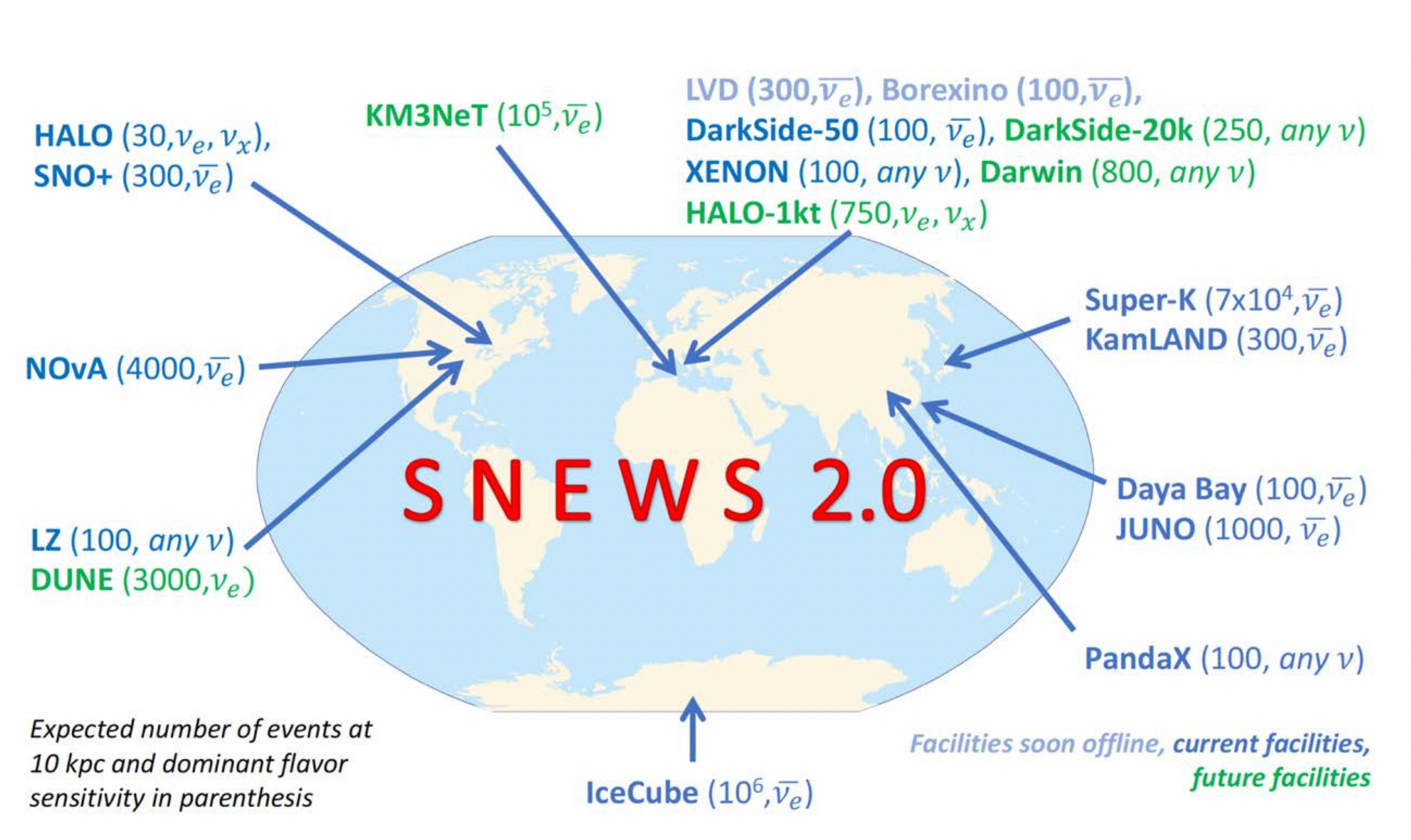
History

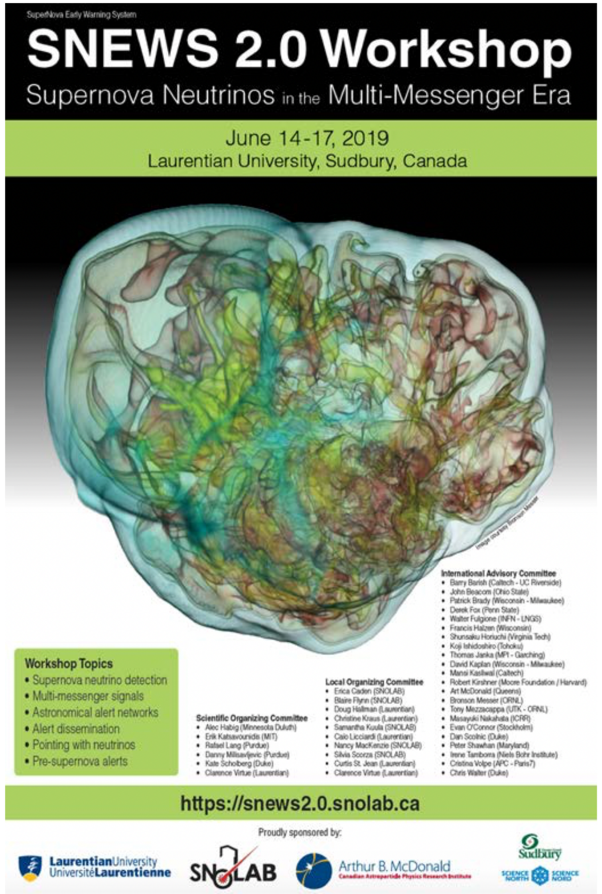


Save-the-data trigger:
NOvA 2015+
XENON1T 2017-2018

Don't stop taking data:
LIGO 2015+

Detectors worldwide

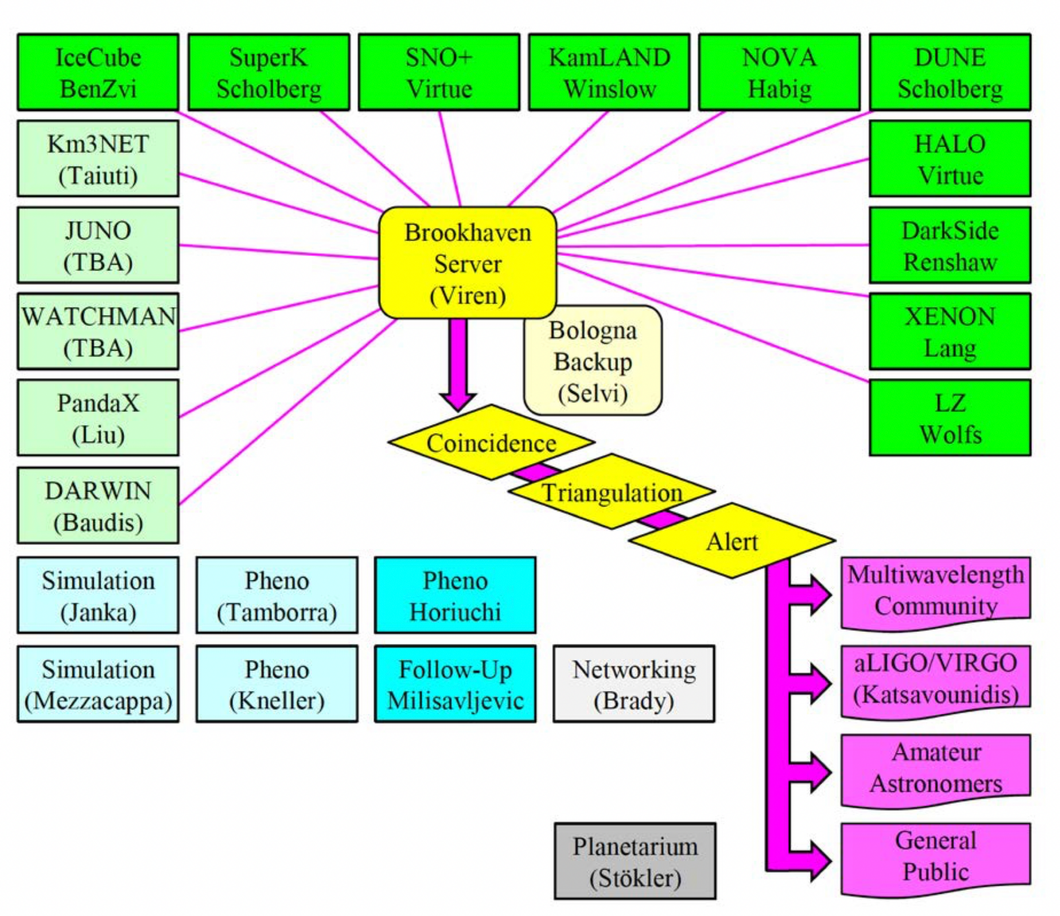




SNEWS 2.0 for the multi-messenger astronomy era

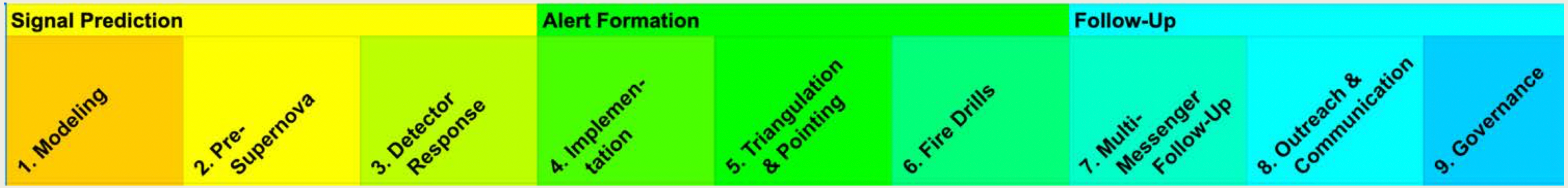
What changed?

- **NSF WoU-MMA: Collaborative Research:** A Next-Generation SuperNova Early Warning System for Multi-messenger Astronomy (Purdue, Duke, Houston, Laurentian, Minnesota, MIT, Rochester, Virginia Tech)
- 2019: SNEWS 2.0 funded
  - *Add dark matter detectors*
  - *Integrate into MMA better*
  - *Triangulation*
  - *Alert drills*
  - *Increased low probability alerts*



MMA INTEGRATION

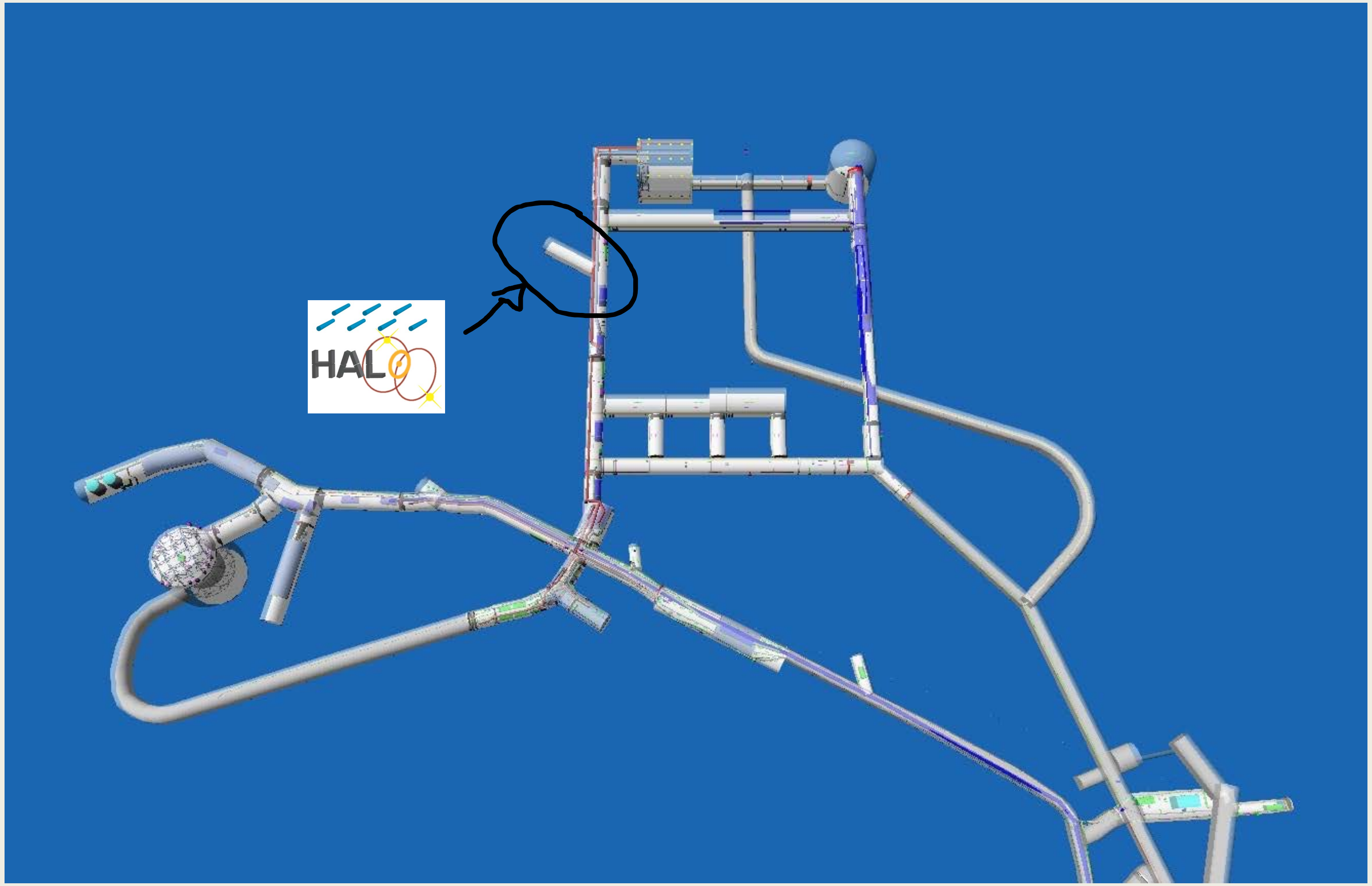
Working Group



- 9 groups as described
  - *Mostly self explanatory*
- Regular calls for each group happening/scheduled

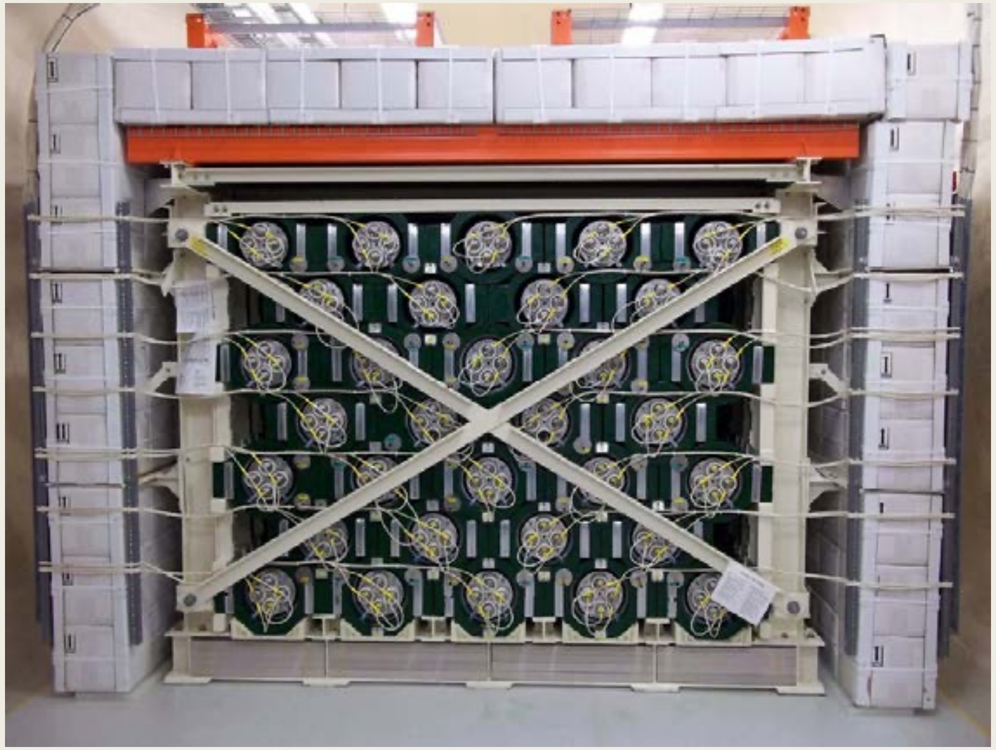
HALO – HELIUM AND LEAD OBSERVATORY

HALO @ SNOLAB



Helium + Lead

- A detector of Opportunity
- Helium – the repurposing of available ^{3}He counters from the final stage of SNO
- Lead – high neutrino-lead cross section, low neutron capture cross section
  - *Lead from decommissioned cosmic ray monitoring system*
    - At chalk river
- LAND: Lead Astronomical Neutrino Detector
  - *C.K. Hargrove et al., Astropart. Phys. 5 183, 1996*
  - *Pre-HALO design/proposal*

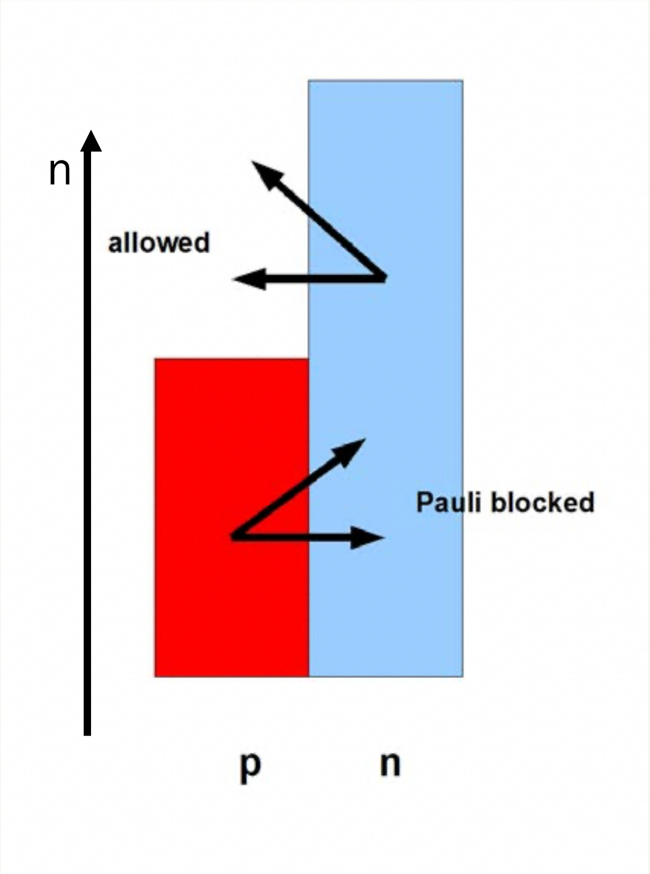


Science Goals

- low cost, low maintenance, long lifetime, dedicated supernova detectors
- Most other detectors have other science goals as well, require downtime, and calibration time
- As costs go up in next generation detectors energy threshold probably will go down to cut costs meaning supernova sensitivity will decrease
- Water Cherenkov & liquid scintillator are sensitive to anti-electron neutrinos, but information from other neutrinos is valuable
- Lead provides dominant electron neutrino sensitivity

Lead as a target

- Largest charged and neutral current cross section of any reasonable material
  - *Higher thresholds*
- The higher the Z the higher the ν_e CC cross section compared to the $\bar{\nu}_e$ CC and NC due to Coulomb enhancement suppressing the $\bar{\nu}_e$ CC channel
- Mainly ν_e sensitive
  - *complimentary water Cherenkov and liquid scintillator detectors*
- De-excitation by 1n or 2n emission following CC or NC interaction
- Neutron excess Pauli blocked (N>>Z)



Neutrino-lead interactions

- Shielded volume of lead w/ helium 3 counters in the lead
- Neutrino reactions for supernova energies shown below
- Electrons carry energy info, could be used to tag CC reactions BUT requires:
  - *Lead in solution: explored & abandoned*
  - *Fine-grained lead scintillator: also abandoned*
  - *No CC tagging or energy measurement*
- Neutron capture can be detected in ^{3}He after thermalization
  - *No energy measurement*
    - Some sensitivity through 2n/1n ratio
    - no direction
    - Only counting as a function of time, 1n and 2n events

$$\begin{aligned}
\text{CC}: \quad & \nu_e + {}^{208}\text{Pb} \rightarrow {}^{207}\text{Bi} + n + e^- - 10.3\,\text{MeV} \\
& \nu_e + {}^{208}\text{Pb} \rightarrow {}^{206}\text{Bi} + 2n + e^- - 18.4\,\text{MeV} \\
\text{NC}: \quad & \nu_x + {}^{208}\text{Pb} \rightarrow {}^{207}\text{Pb} + n - 7.4\,\text{MeV} \\
& \nu_x + {}^{208}\text{Pb} \rightarrow {}^{206}\text{Pb} + 2n - 14.1\,\text{MeV}
\end{aligned}$$

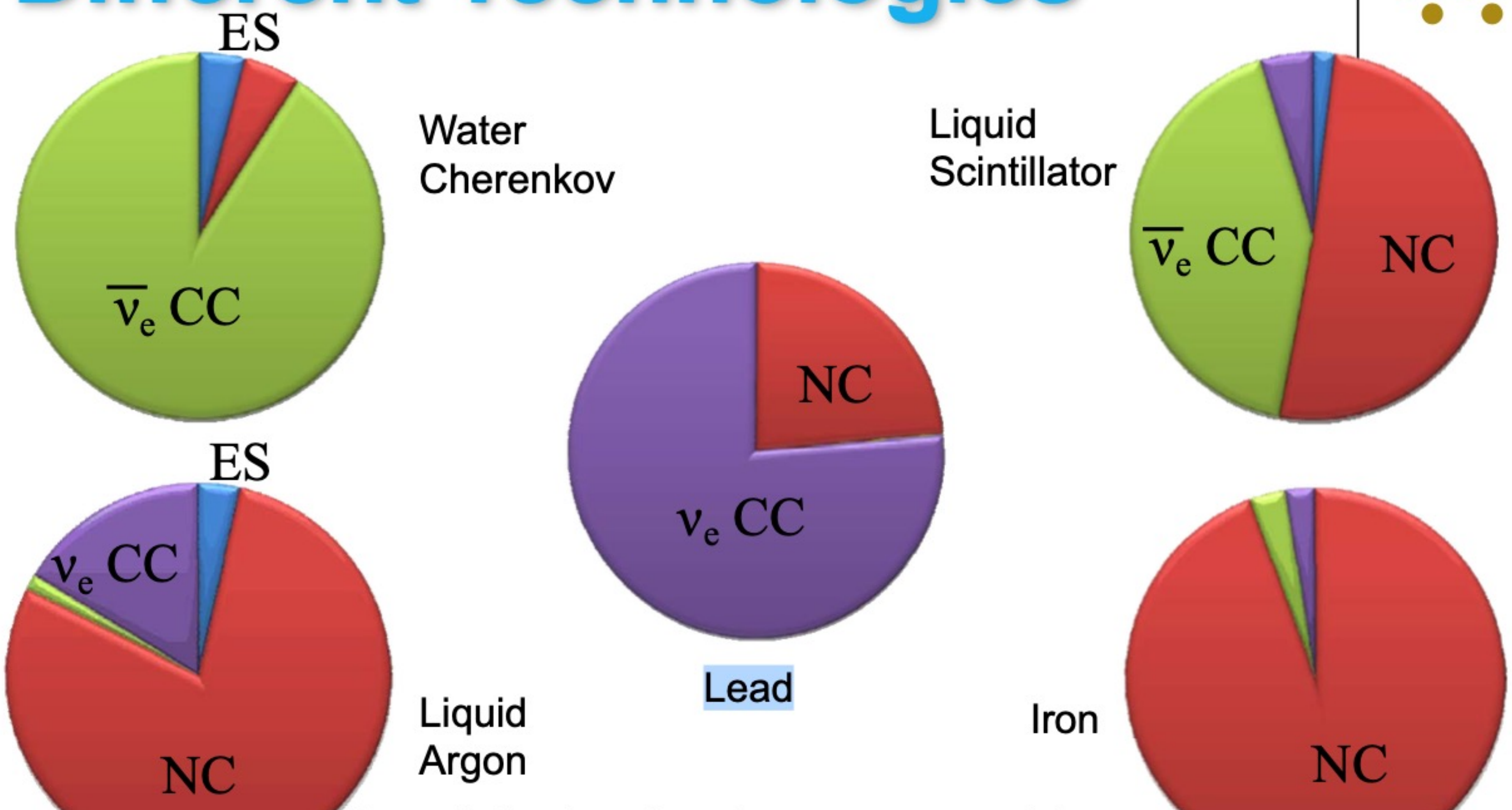
Other lead-based detector Pros and Cons

- No (α, n) - high Coulomb barrier
- Low neutron absorption cross section
  - *Lowest in table of isotopes*
  - *"good" medium for moderating neutrons down to epithermal energies*
  - *Achieve 50-55% n capture on ^{3}He*
- Low maintenance and operating cost
- Robust and Compact

Downsides:

- No directionality
- No CC tagging
- No direct measuring of ν energy

Flavour Sensitivities for Different Technologies

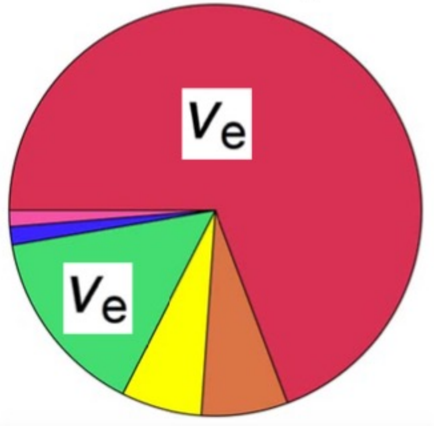


Generally functions of neutrino temperatures and detector energy thresholds, also needs updating for large θ_{13}

Borrowed from C. Virtue

HALO Flavour Sensitivity

- the nuclear physics of lead strongly affects the interaction rates
  - the neutron excess in Pb Pauli blocks ν_e CC reactions
  - the high Z further Coulomb suppresses $\overline{\nu}_e$ CC and enhances ν_e CC
- the response remains an unresolved mixture of ν_e CC and ν_x NC but is largely orthogonal to $\overline{\nu}_e$ CC (IBD) sensitivity of LS and WC detectors
- part of the merit of a lead-based supernova detector rests on its complementary flavour sensitivity wrt other SN detectors and the power it brings to joint analyses



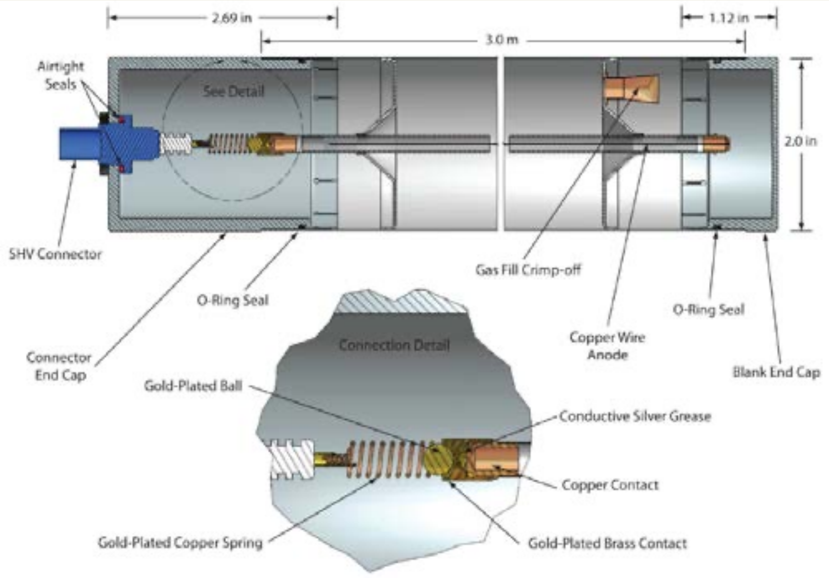
- $^{208}Pb\ (\nu_e, e^-)\ ^{207}Bi + n$
- $^{208}Pb\ (\nu_x, \nu_x)\ ^{207}Pb + n$
- $^{208}Pb\ (\overline{\nu}_x, \overline{\nu}_x)\ ^{207}Pb + n$
- $^{208}Pb\ (\nu_e, e^-)\ ^{206}Bi + 2n$
- $^{208}Pb\ (\nu_x, \nu_x)\ ^{206}Pb + 2n$
- $^{208}Pb\ (\overline{\nu}_x, \overline{\nu}_x)\ ^{206}Pb + 2n$

A. Gallo Rosso

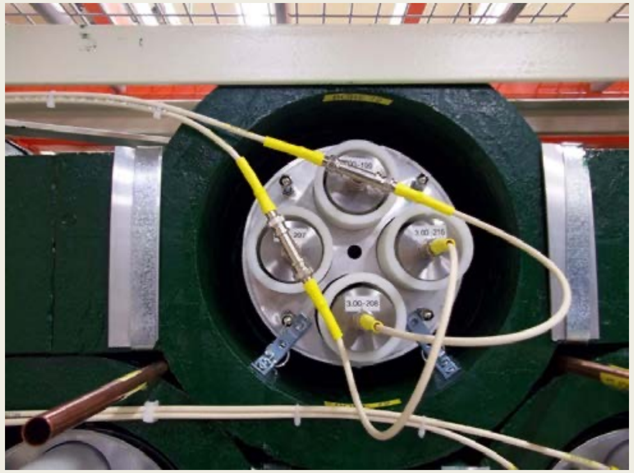
May 13, 2020 40

Borrowed from C. Virtue

He 3 counters

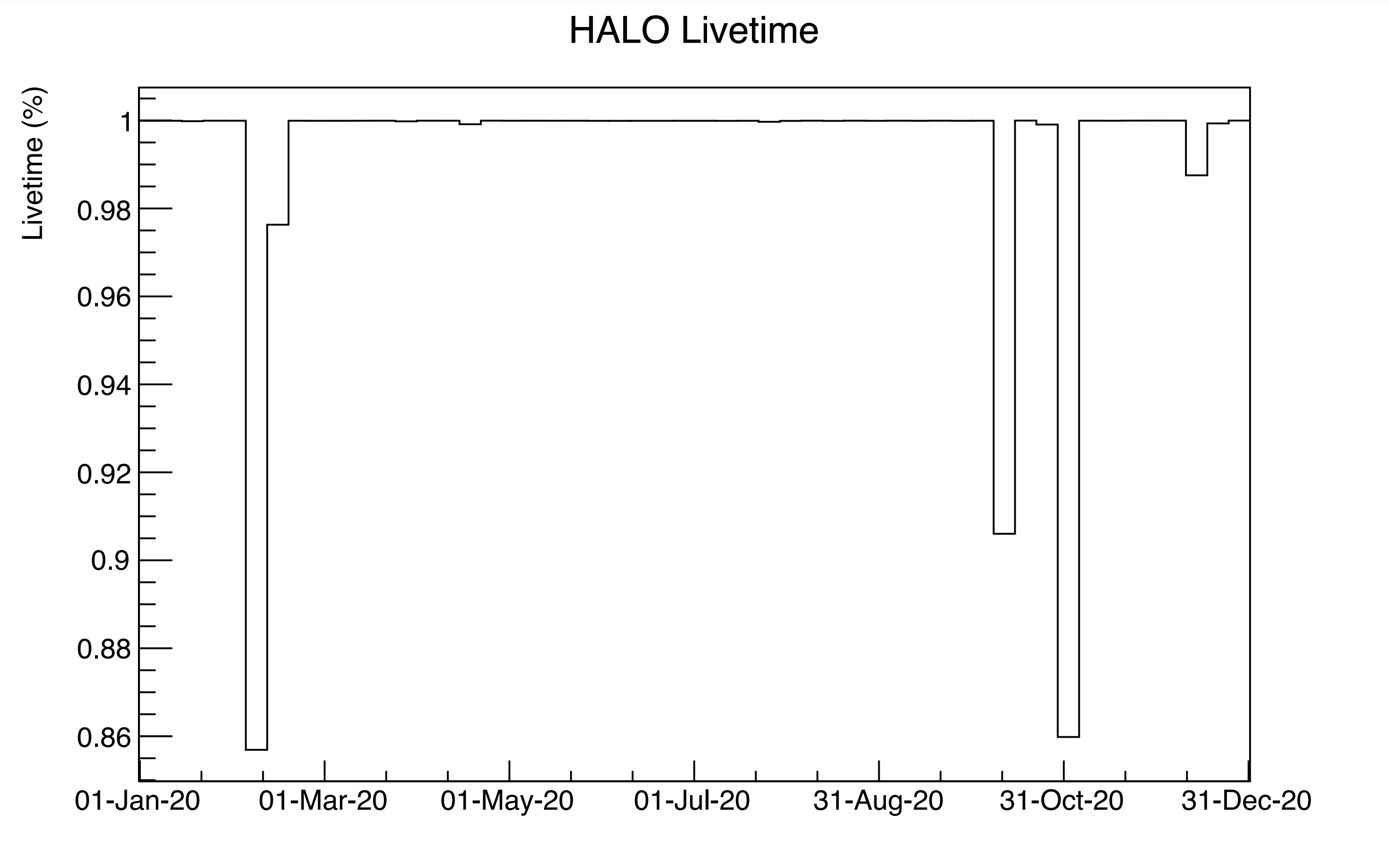


- SNO's NCDs – he3 proportional counters
- 5 cm diameter x 3m and 2.5m in length, ultra-pure CVD Ni tube (600 micron wall thickness)
- 2.5 atm (85% 3He, 15% CF4, by pressure)
- 128 counters, paired to 64 channels
  - *370m of counters*
- 4 counters per each column of lead
  - *HDPE moderator tubes*
  - *32 columns of lead*
- $He^3 + n \rightarrow {}^3H + p, (Q = 764KeV)$



SNEWS trigger

- 4 events in neutron window in 2 seconds
- At 15mHz neutron rate random coincidences are expected once/2years
- Spallation events are suppressed
  - *Over in <1ms*
  - *Don't generate a SNEWS trigger*
  - *Not limited by background rates*
- Sensitivity to 18 kpc
  - *Limited by target mass*



Status today

- Full detector being read out since May 8, 2012
- Daily shifts since July 27, 2012
- Connected to SNEWS w/ burst implementation Oct 8, 2015
- 99.19% uptime in 2020

COLLABORATION

Taken from the Halo website: snolab.ca/halo

Member Institutions
of the Helium and Lead Observatory

PARTICIPATING INSTITUTIONS:

Armstrong Atlantic State University
Jeff Secrest

Center for Experimental Nuclear Physics and Astrophysics, and University of Washington
Hamish Robertson

Digipen Institute of Technology
Charles Duba

Duke University
Kate Scholberg, Roger Wendell

Laurentian University
Jacques Farine, Alicja Kielbik, Christine Kraus, Michael Schumaker, Taylor Shantz,Clarence Virtue*

Los Alamos National Laboratory
Andrew Hime

SNOLAB
Fraser Duncan

Technische Universität Dresden
Kai Zuber

TRIUMF
Stanley Yen

University of Minnesota Duluth
Alec Habig

University of North Carolina
Mark Howe, John Wilkerson

* HALO Spokesperson

FORMER COLLABORATING MEMBERS:

Laurentian University
Fabrice Fleurot, Stephen Korte

Co-op/Summer Students
Philipp Bauer (SNOLAB), Ben Bellis (Duke), Axel Boeltzig (SNOLAB), Victor Buza (UMD), Nicolas Kaiser (Duke), Andre Labelle (Laurentian), Terry Massicotte (Laurentian), Zander Moss (Duke), Kurt Nicholson (SNOLAB), Andre-Philippe Olds (Laurentian), Steven Rayan (Laurentian), Brian Redden (Armstrong), Leigh Schaefer (Duke), Olivia Zigler (UMD)

MANY THANKS TO:

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Ken McFarlane

SNOLAB
Oleg Li, Brian Morissette, and the SNOLAB staff

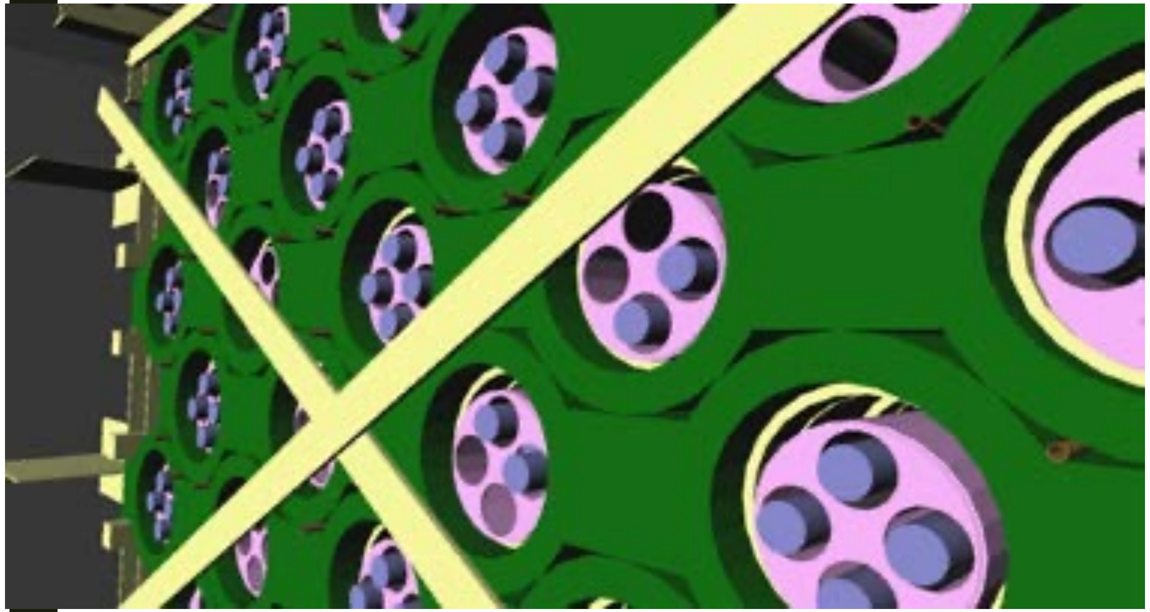
Duke University
Jack Fowler

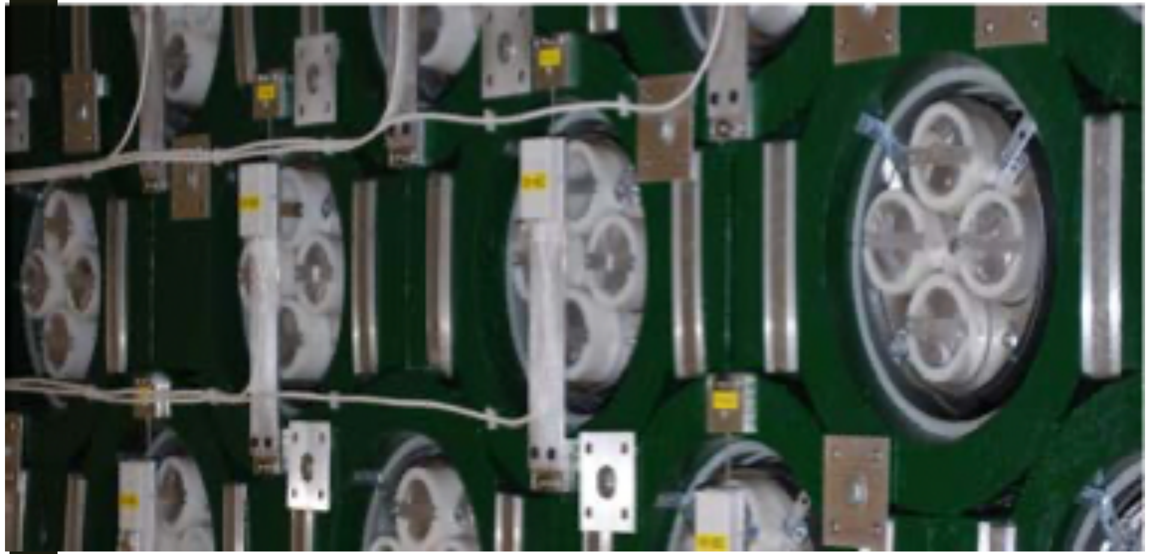
CONTACT INFORMATION:

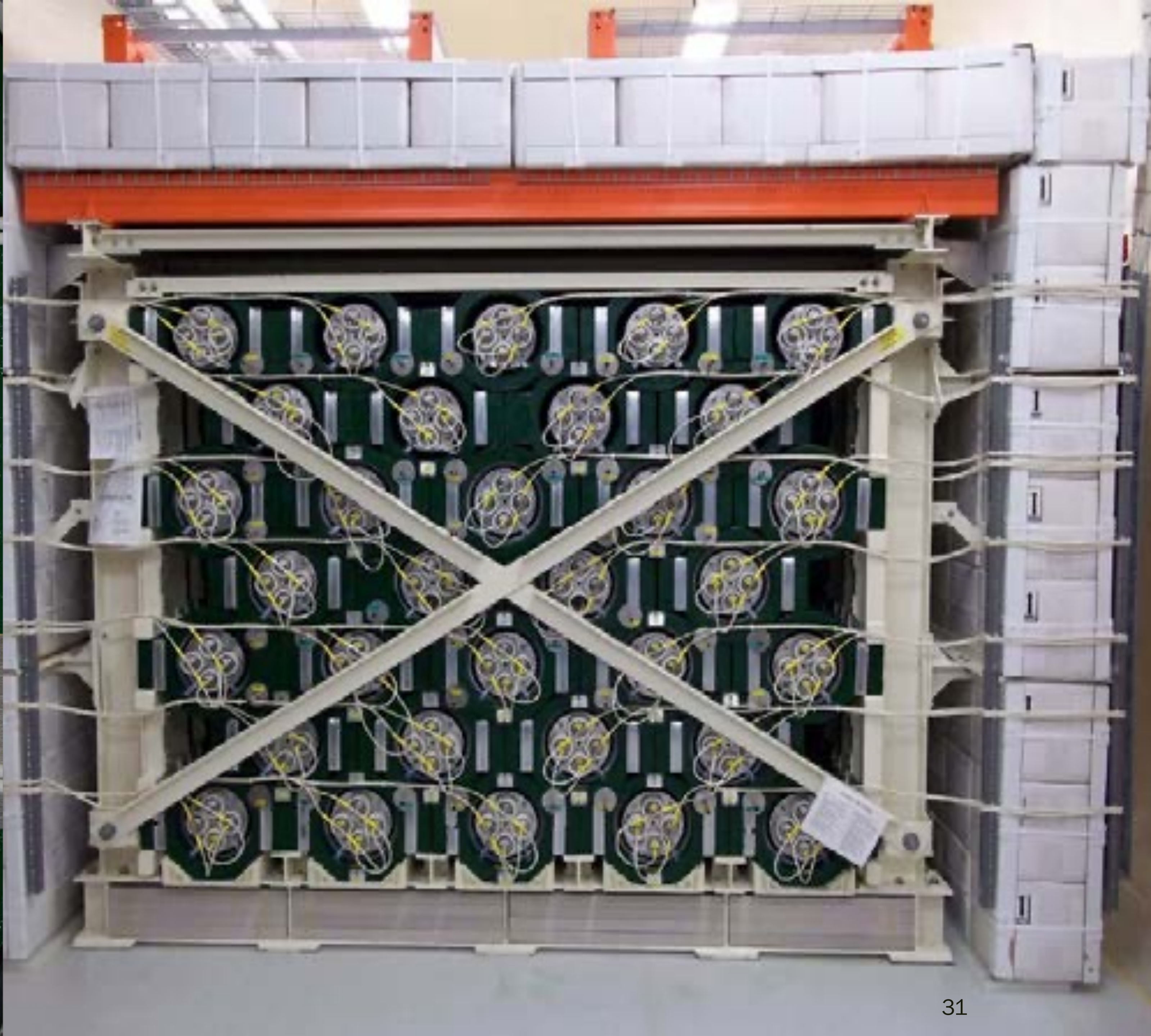
Dr. C.J. Virtue
Laurentian University
Department of Physics
935 Ramsey Lake Road
Sudbury, ON
Canada P3E 6C1

Tel. +1 705 675-1151 x2223

cjv#snolab.ca



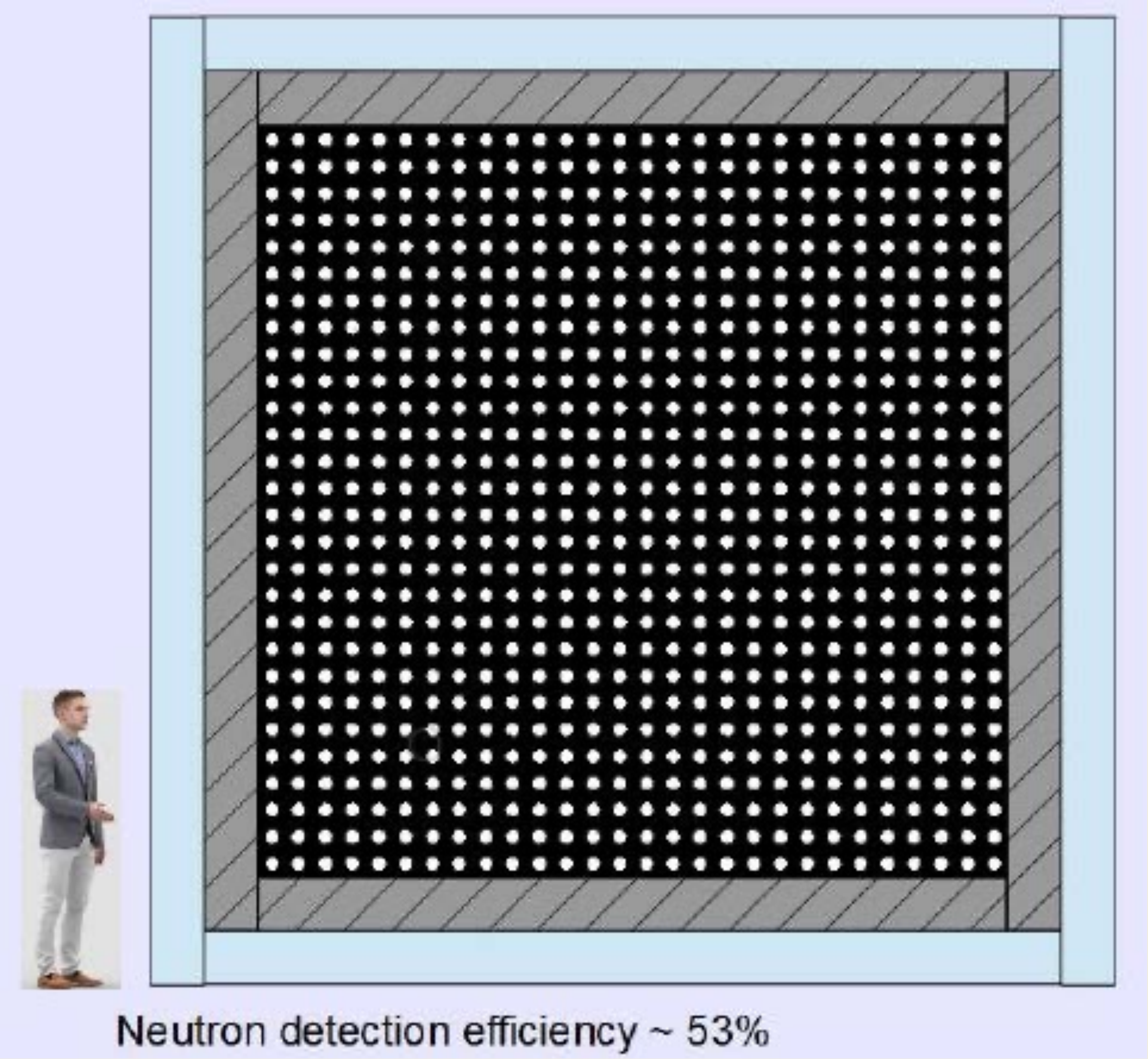


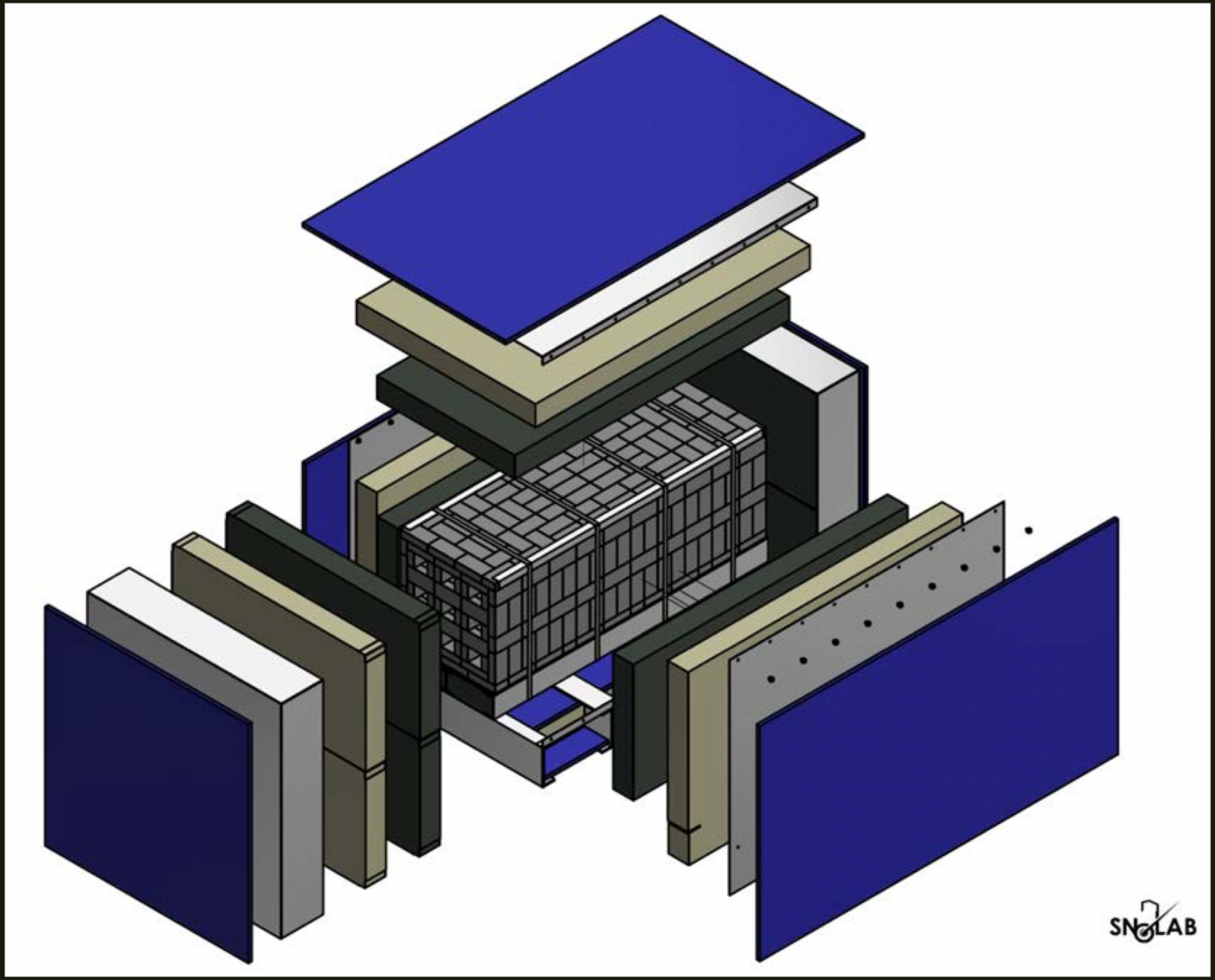

CM-42
SPB-42



RACK 0
RACK 1
RACK 2

HALO-1kT

- HALO was a working prototype
  - *Going from 79T to 1kT*
  - *28% to 50% n capture efficiency*
  - *23 x the event statistics*
- Approx. 4.3km of proportional counters
  - *28x28x5.5m array*
- 30 cm graphite reflector
- 30 cm HDPE shielding





Mini-Halo

- Unique among lead detectors – not meant to measure SN neutrinos
- At SNS neutrino lead cross sections
- Integrate over neutrino energy
- 10 T of lead

QUESTIONS?

Thank you