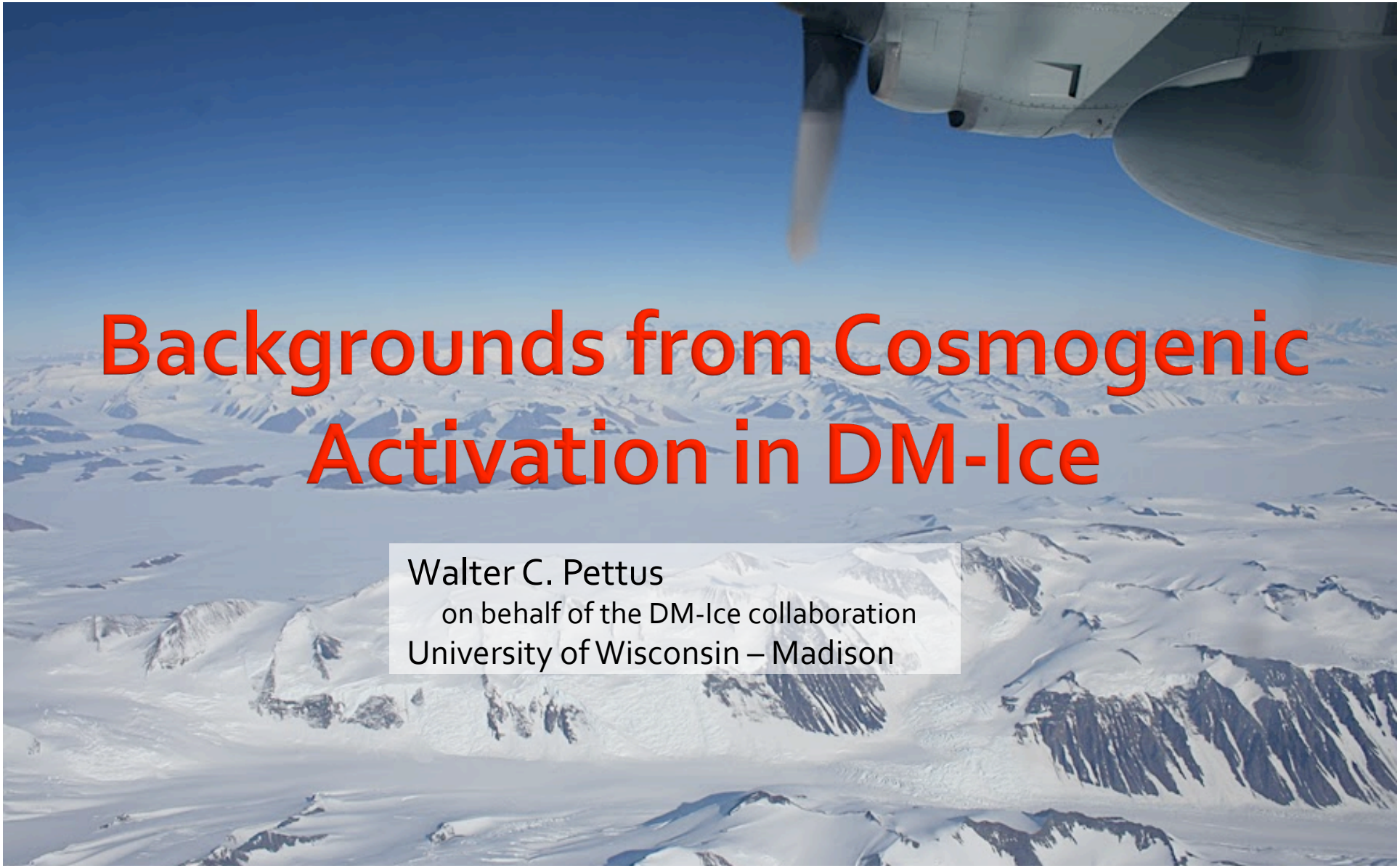


Backgrounds from Cosmogenic Activation in DM-Ice

Walter C. Pettus
on behalf of the DM-Ice collaboration
University of Wisconsin – Madison

STEWARDSHIP SCIENCE GRADUATE FELLOWSHIP

IPA 2015
Madison, WI
4 – 6 May 2015

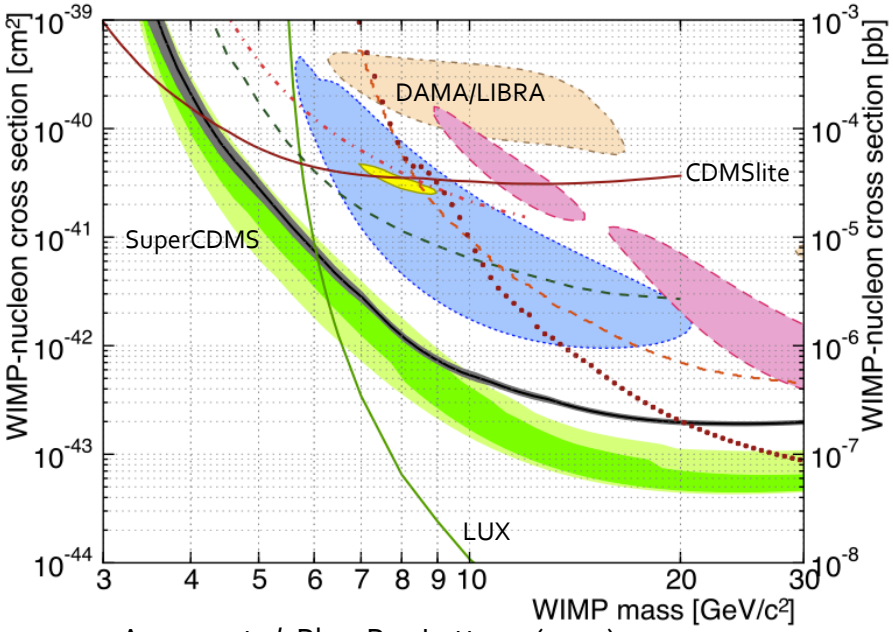
WIPAC
Wisconsin IceCube Particle Astrophysics Center

THE UNIVERSITY of WISCONSIN MADISON

Tension of Experimental Results

Exclusion Limits vs. Low-Mass WIMP Hints

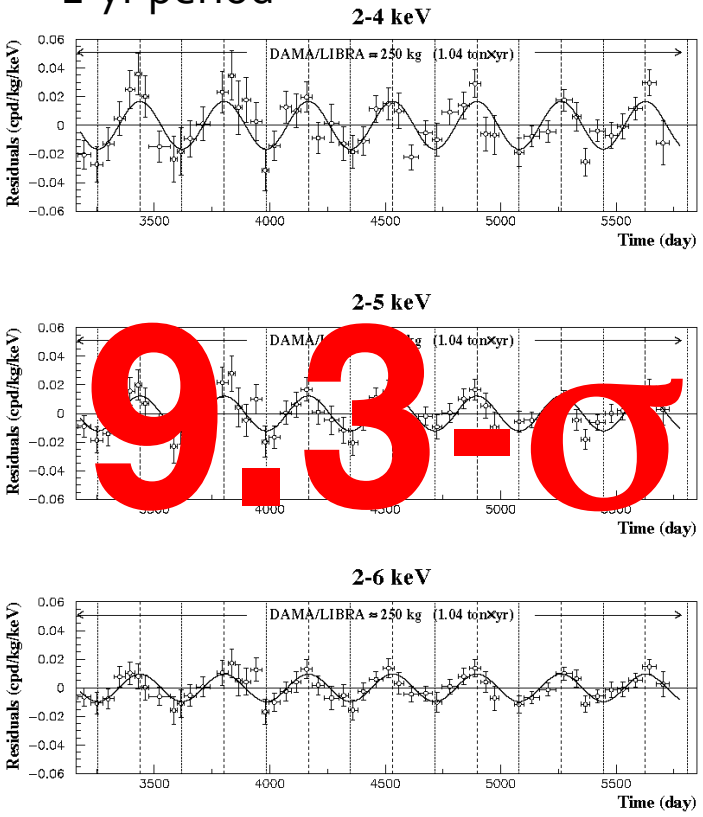
Multiple experiments strongly disfavor dark matter interpretation of DAMA



Agnese *et al.* Phys Rev Lett 112 (2014)

Persistent Signal

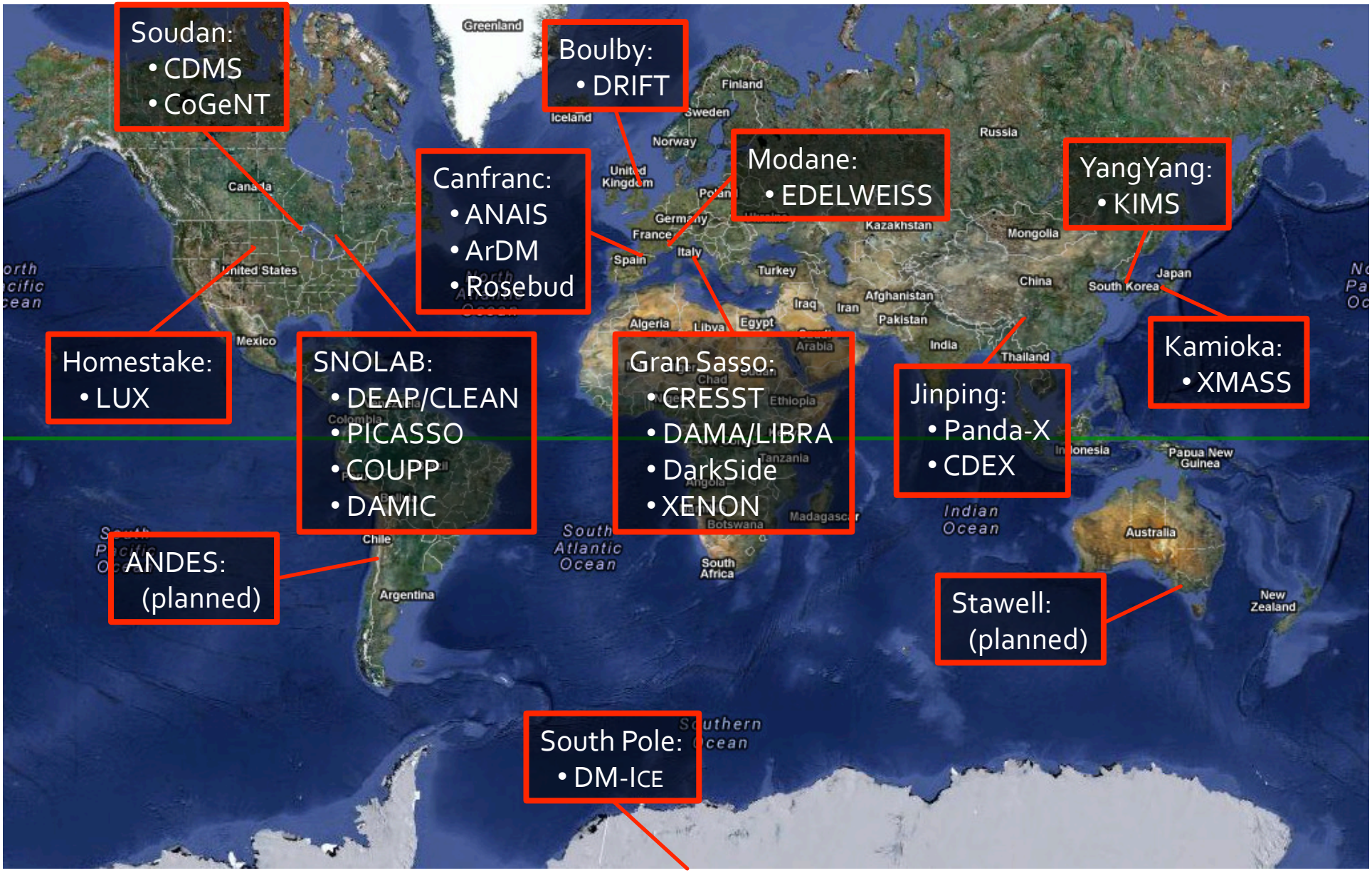
DAMA/LIBRA-phase1 (1.04 ton*yr): Consistent signal modulating with 1-yr period



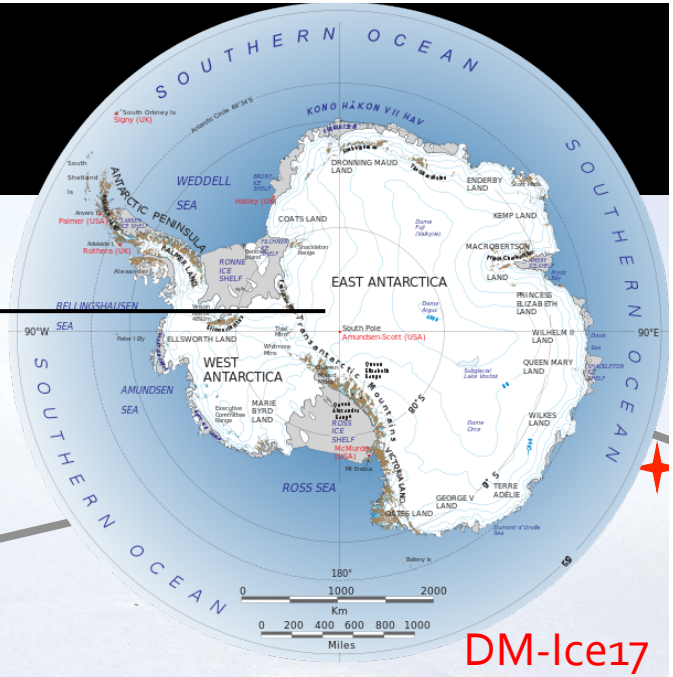
Bernabei *et al.* Eur. Phys. J. C 73 (2013)

Resolution hidden in Astrophysics, Particle Physics, Instrumental Effects, or Background?

A World of Dark Matter Searches



South Pole Science



Geographic South Pole

Amundsen-Scott South Pole Station

Skiway

DM-Ice17

IceCube
IceTop

Keck Array

BICEP3, SPT

DM-Ice17 Experiment

(2x) 8.5-kg NaI(Tl) modules

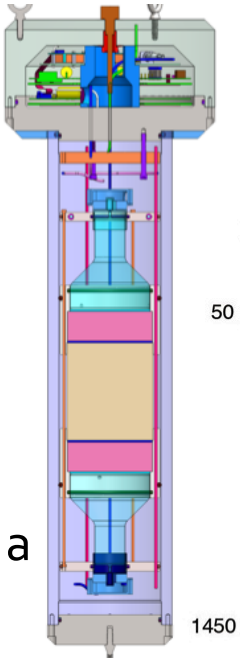
- Installed Dec 2010
- Data run from June 2011

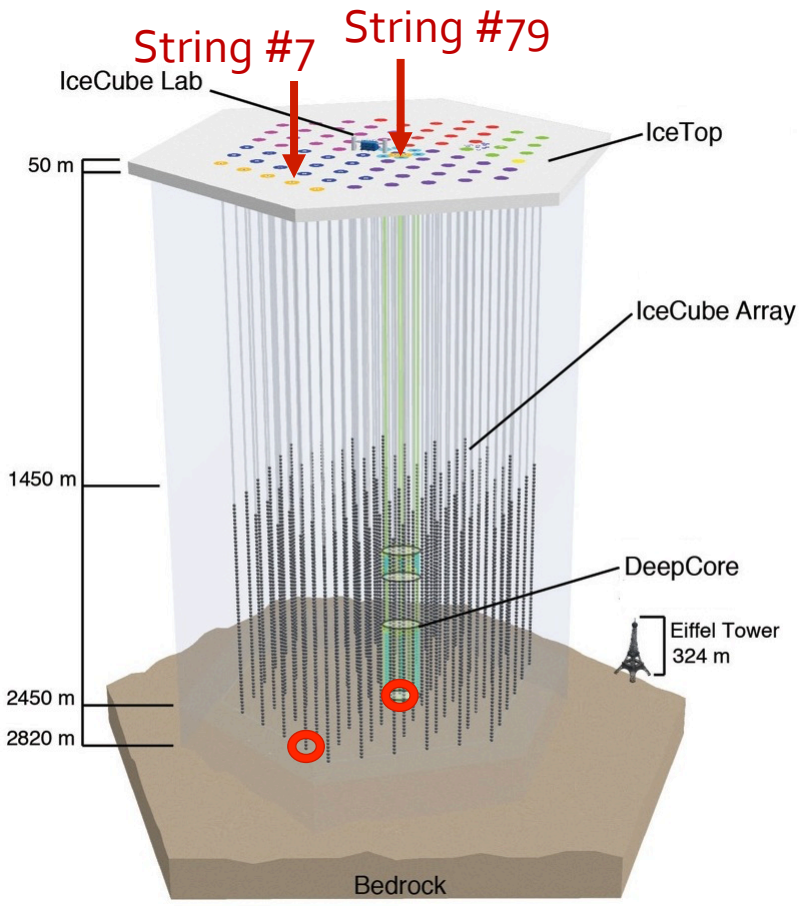
Goals:

- Demonstrate the feasibility of deploying and operating NaI(Tl) detectors in the Antarctic Ice for a dark matter search
- *In situ* measurement of the radiopurity of the Antarctic ice / hole ice at 2450 m depth
- Study environmental stability

  (*see Z. Pierpoint, this session*)
- Study the capability of IceCube to veto muons

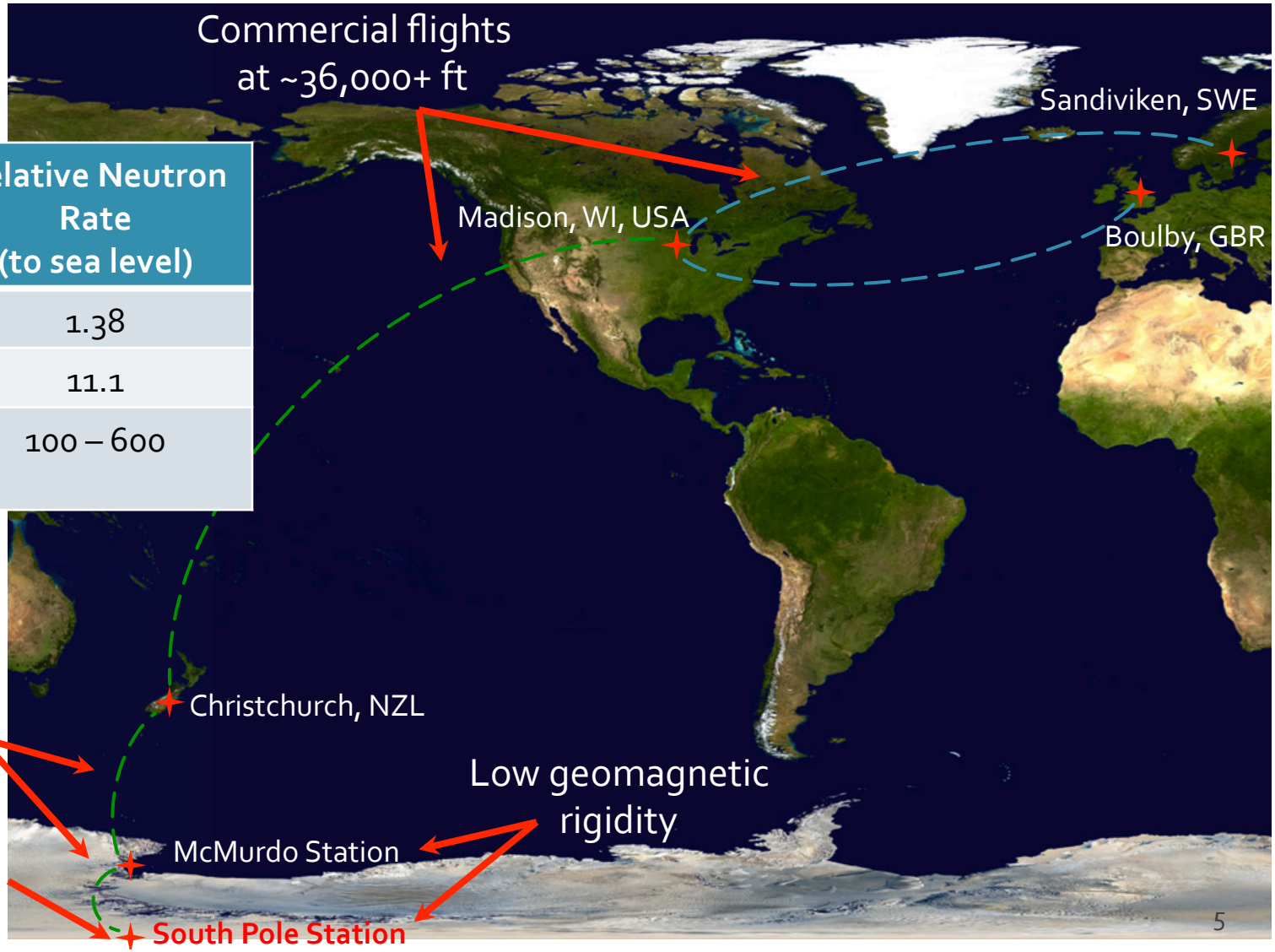
  (*see A. Hubbard, this session*)





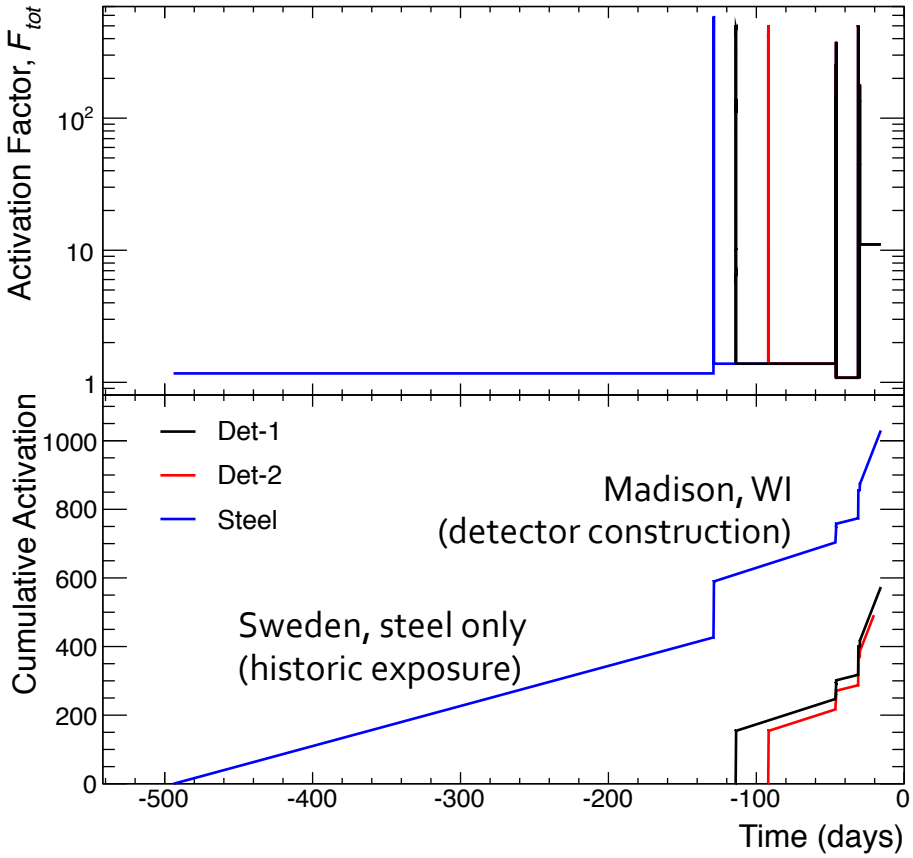
Cosmogenic Activation Hazards

Location	Relative Neutron Rate (to sea level)
Madison, WI	1.38
South Pole	11.1
Commercial Flight	100 – 600



Cosmic Ray Exposure Timeline

Full Detector Component History



F_{tot} – Relative cosmic ray neutron flux (scaling from sea level)

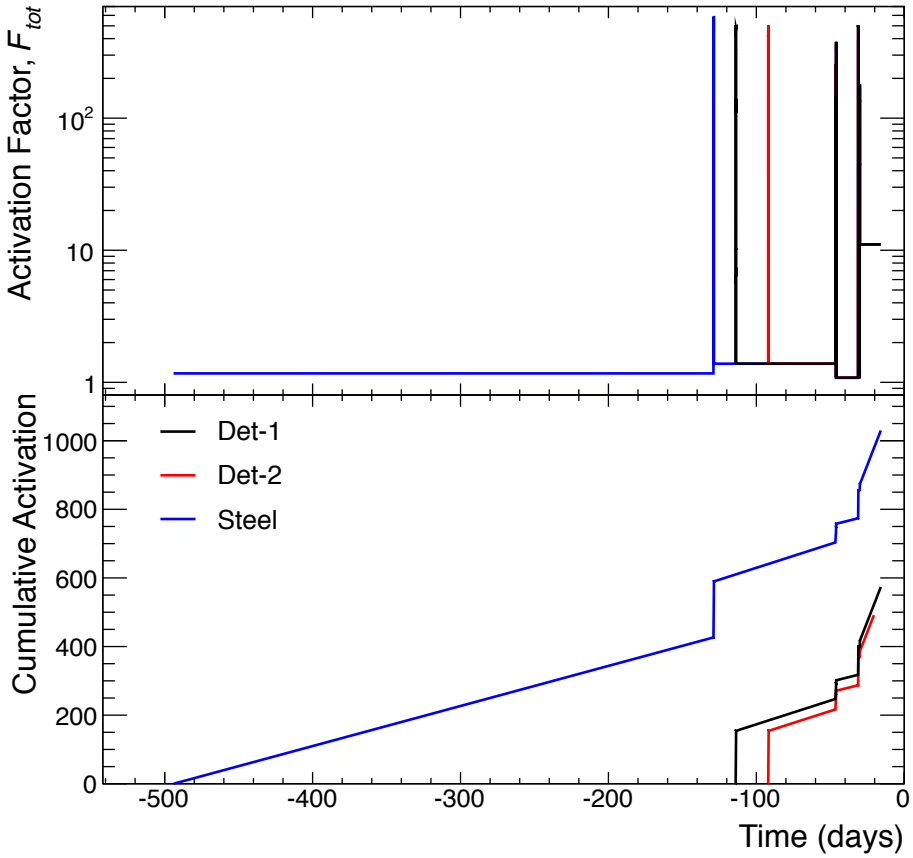
- Long periods of low-level exposure during storage and construction
- Punctuated exposure from flight shipment

"Cumulative Activation" – Time-integrated neutron flux scaling

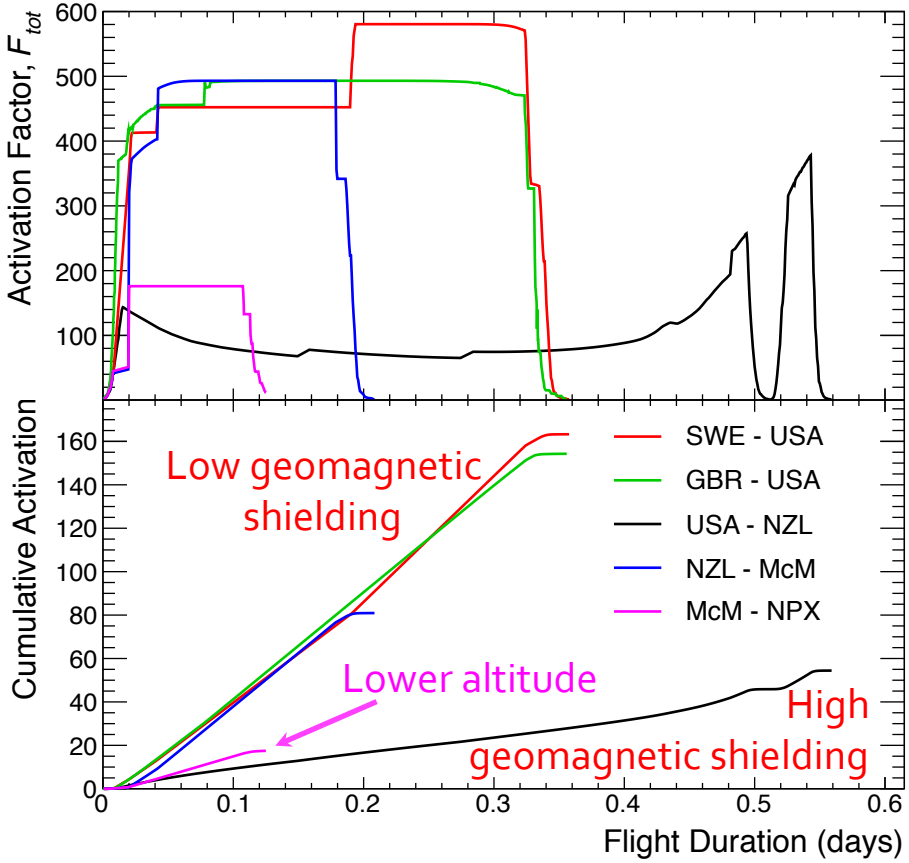
- Different detector components have different exposure histories
- Two DM-Ice17 detectors have different deployment times

Cosmic Ray Exposure Timeline

Full Detector Component History



Flight Segments

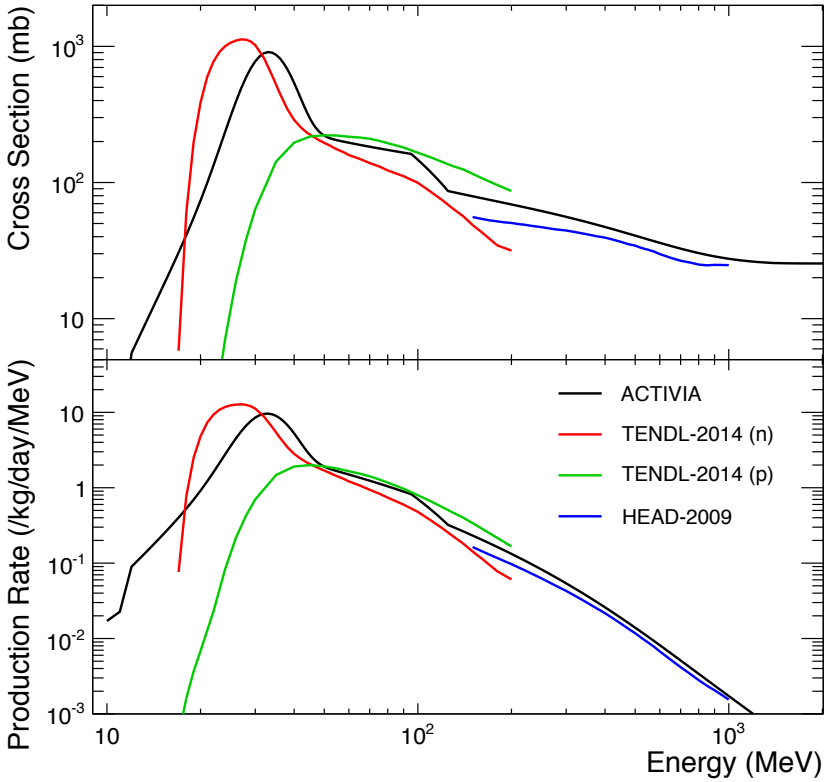


Activation Calculation

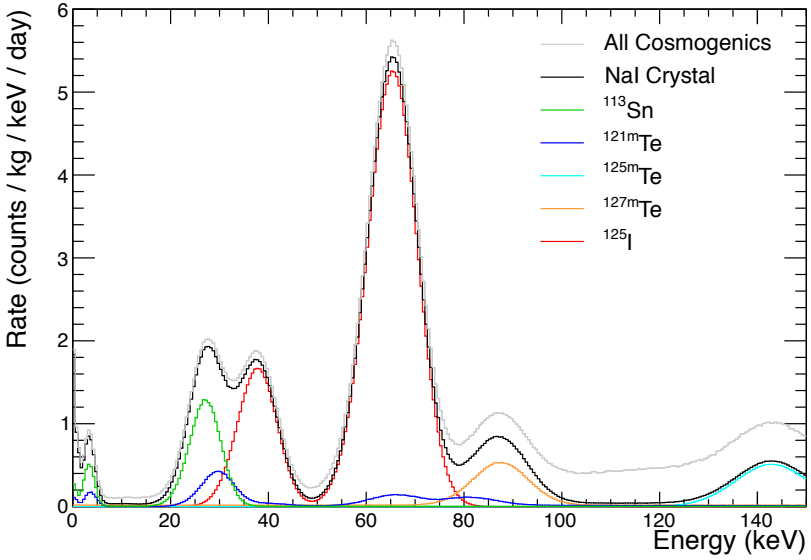
Calculate sea-level activation:

- Identify isotopes of interest from activation code (ACTIVIA)
- Validate cross section against libraries (TENDL, HEAD)
- Integrate over cosmic ray neutron flux

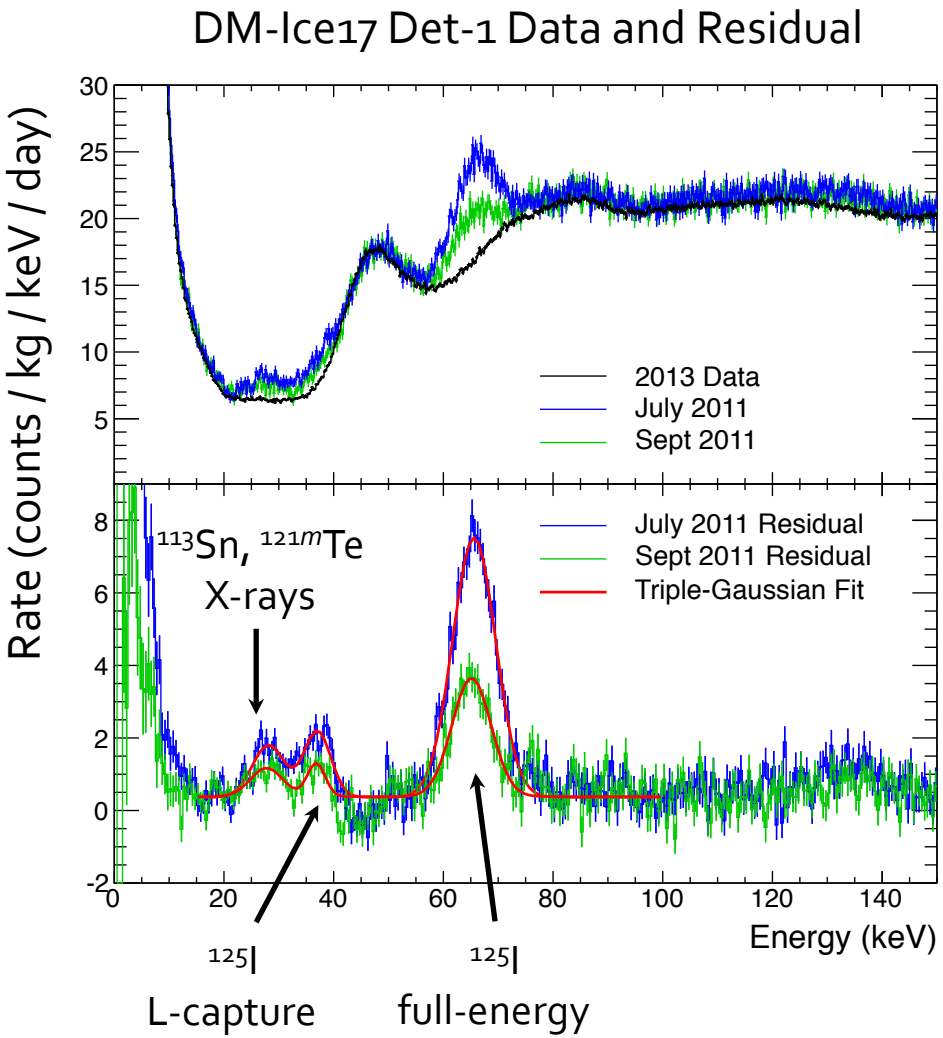
$$R \propto \int \phi_n(E) \cdot \sigma(E) \cdot dE$$



- Scale isotope production by exposure history
- Allow decay governed by known half-lives

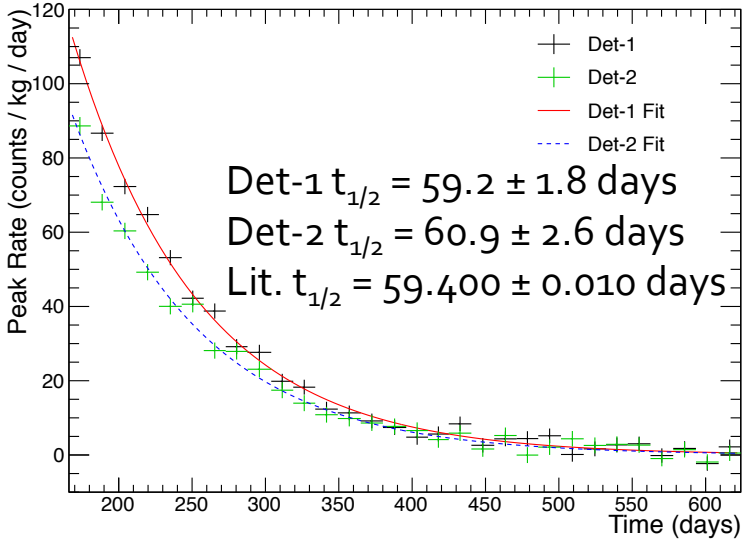


Cosmogenic Decay Peaks



Confirm identity of cosmogenic peaks:

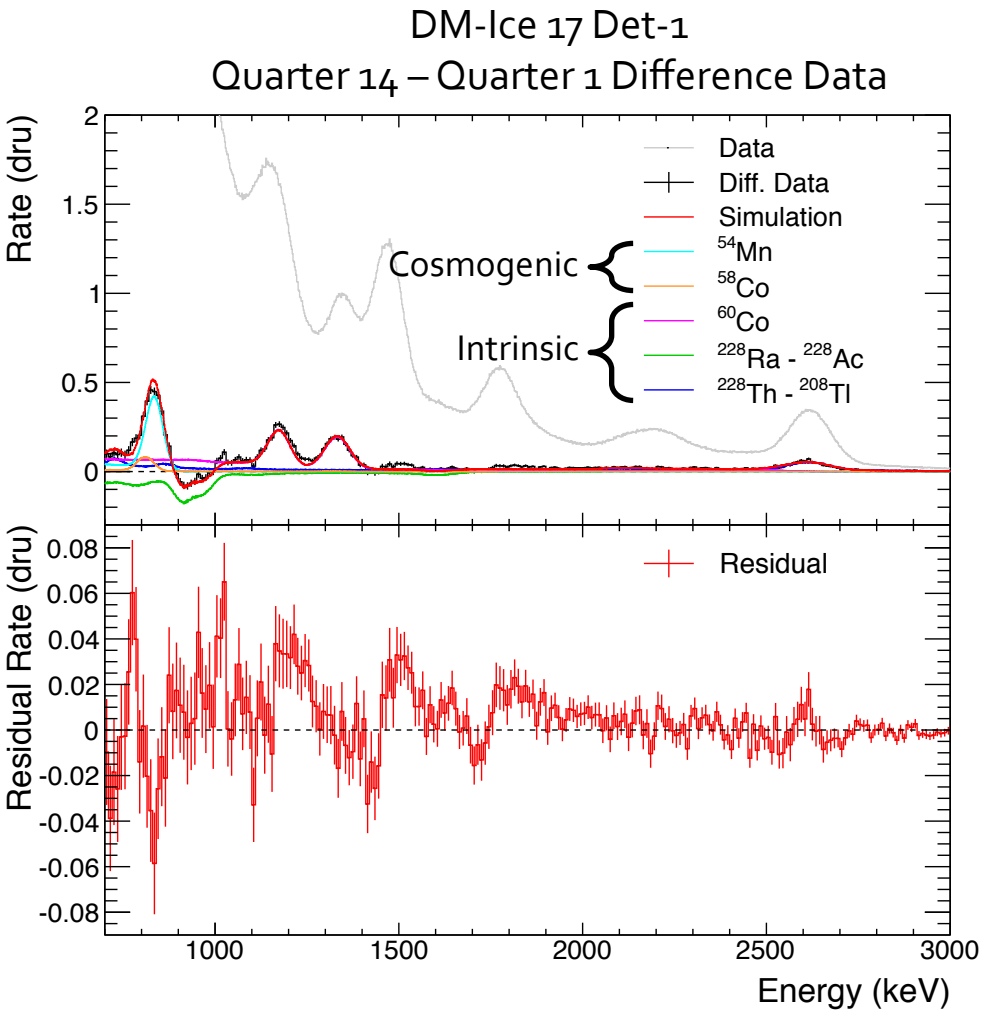
- Match simulated spectral features
  - Expect 65.3 keV full-energy and 37.6 keV L-shell capture peaks for ^{125}I
- Measuring decay time
  - Expect 59.4 day half-life for ^{125}I



High-Energy Spectrum

Examining changing spectrum at high-energy

- Demonstrates presence of cosmogenic decays
  - ^{54}Mn ($t_{1/2}$ = 312 days) and ^{58}Co ($t_{1/2}$ = 71 days)
- Reveals decay of intrinsic contaminants
  - ^{60}Co ($t_{1/2}$ = 5.3 yr) in steel pressure vessel
  - Maximally broken ^{232}Th-chain in steel



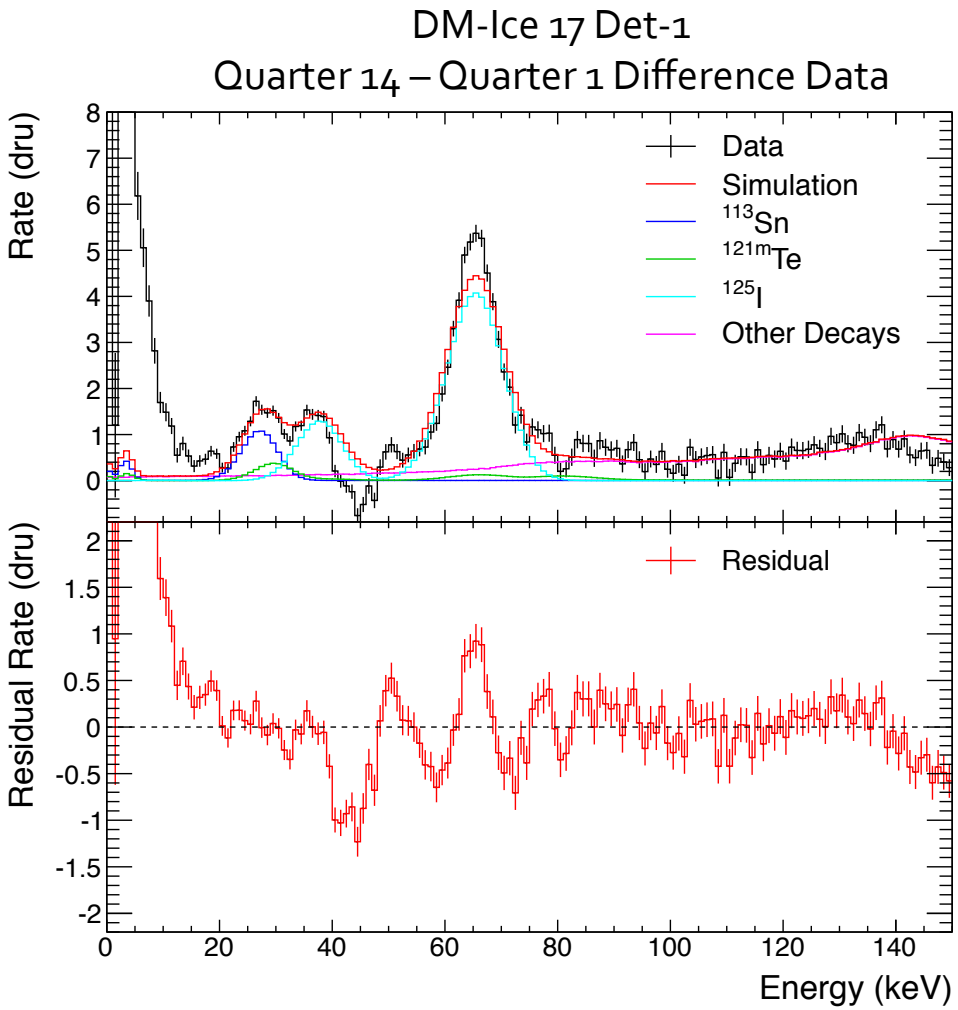
Low-Energy Spectrum

Low-energy spectrum has fewer features, but all cosmogenic:

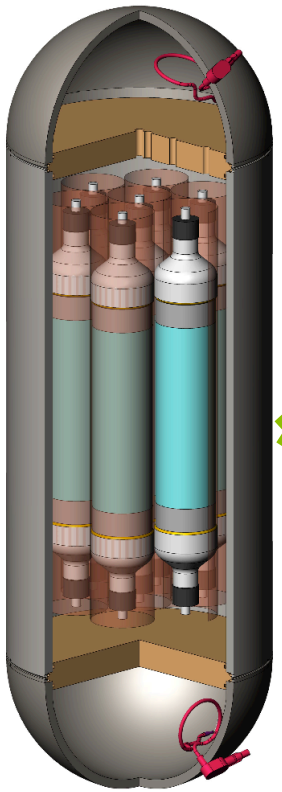
- ^{125}I ($t_{1/2}$ = 59 days)
  - only low-energy features
- ^{113}Sn ($t_{1/2}$ = 115 days) and ^{121m}Te ($t_{1/2}$ = 164 days)
  - Constrained by peaks at 200 – 700 keV

Provides feedback to energy resolution for simulation

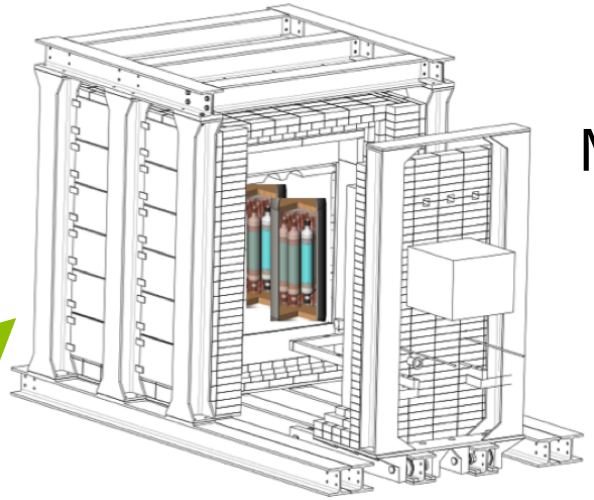
- Significant overestimate for both ^{125}I peaks



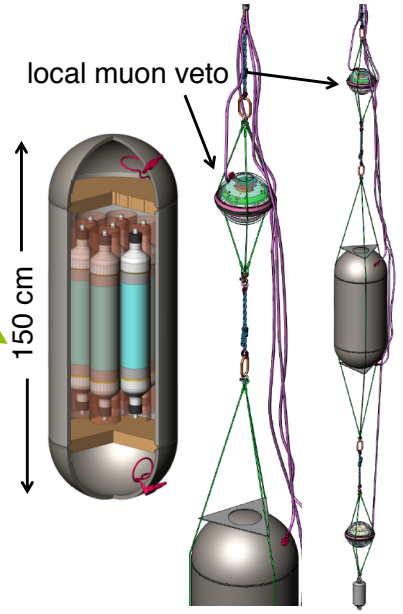
DM-Ice250 Experimental Program



DM-Ice250N



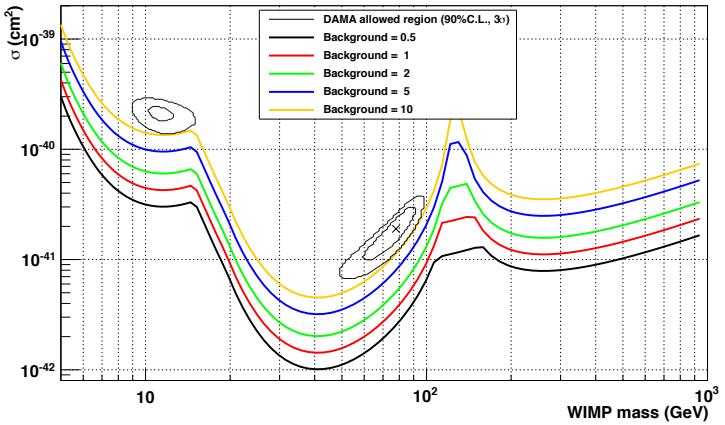
DM-Ice250S



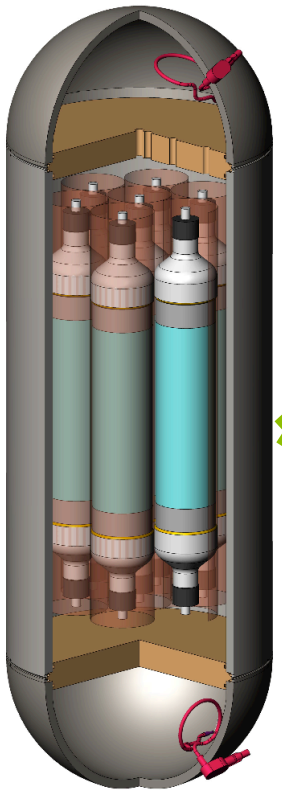
Modular detector supporting deployment in both hemispheres

- 125 kg NaI(Tl) / module
- 7-crystal array

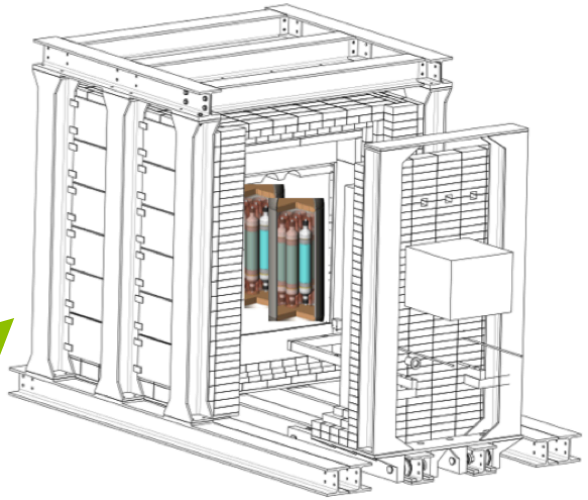
Sensitivity to test DAMA in 500 kg*yr:



DM-Ice250 Experimental Program



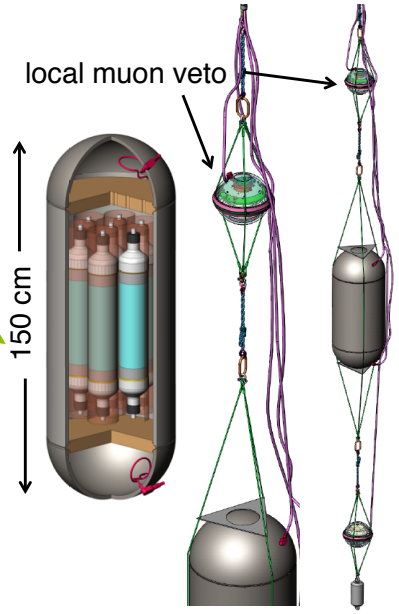
DM-Ice250N



Few cosmogenic activation concerns

- Standard mitigation techniques

DM-Ice250S



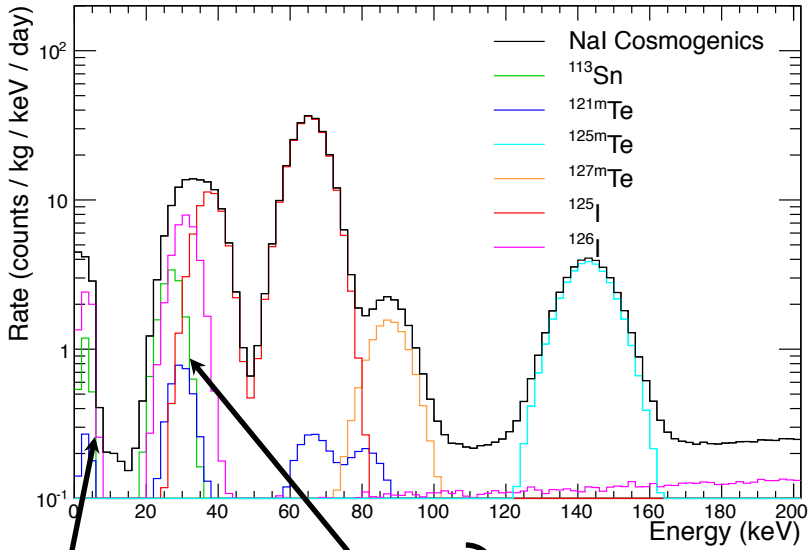
Significant cosmogenic activation concerns

- Novel mitigation techniques required

DM-Ice250S Cosmogenics

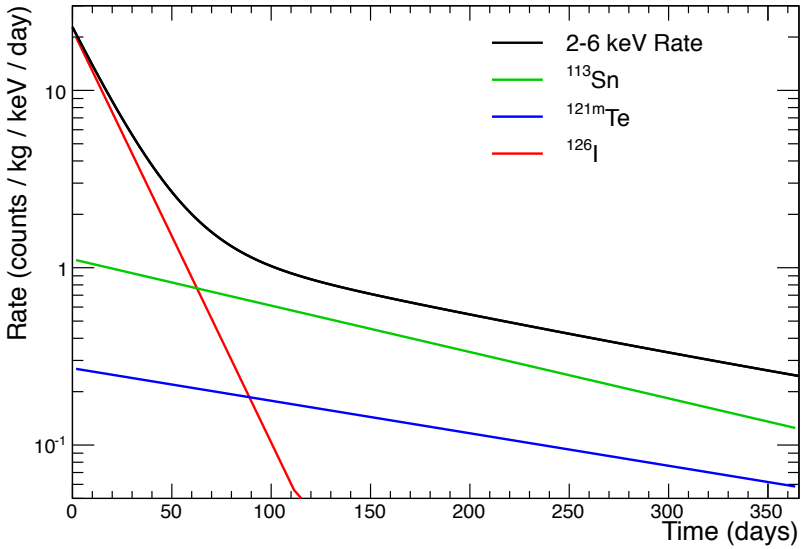
Event rate one month after deployment

- Multiple strong cosmogenic calibration lines
- Significant contributions to 2 – 6 keV region of interest



Cosmogenic contribution to ROI:

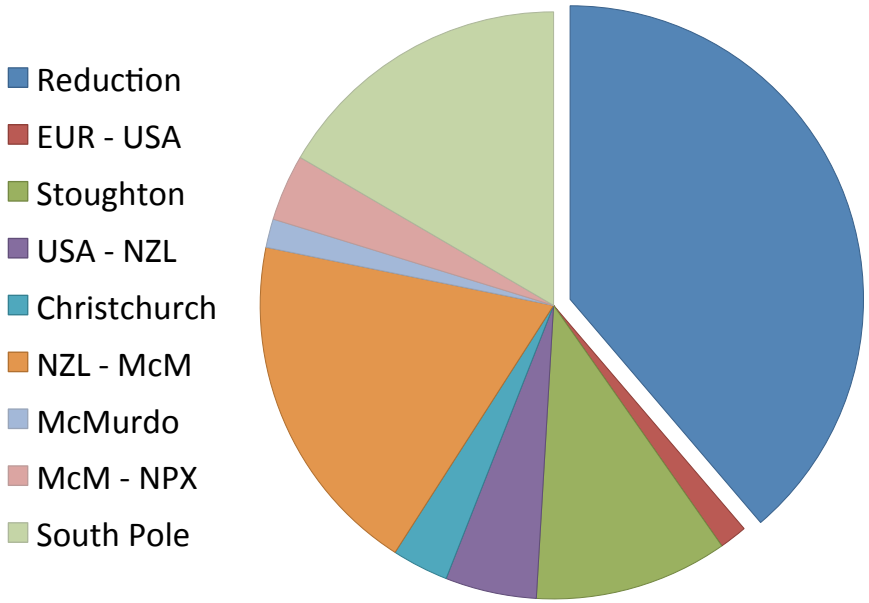
- ^{126}I ($t_{1/2}$ = 13 days)
  - lead contribution at deployment
- ^{113}Sn ($t_{1/2}$ = 115 days)
  - dominates rate over physics run



Cosmogenic Mitigation

"Exposure budget" for ^{113}Sn in DM-Ice250S:

- 40% reduction is "easy"
- Major contributions remain from NZL-McM flight and South Pole



Further reductions:

- 50% reduction in low-altitude NZL-McM flight (10% of total)
- 90% reduction in South Pole exposure from tunnel storage

DM-Ice Collaboration

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