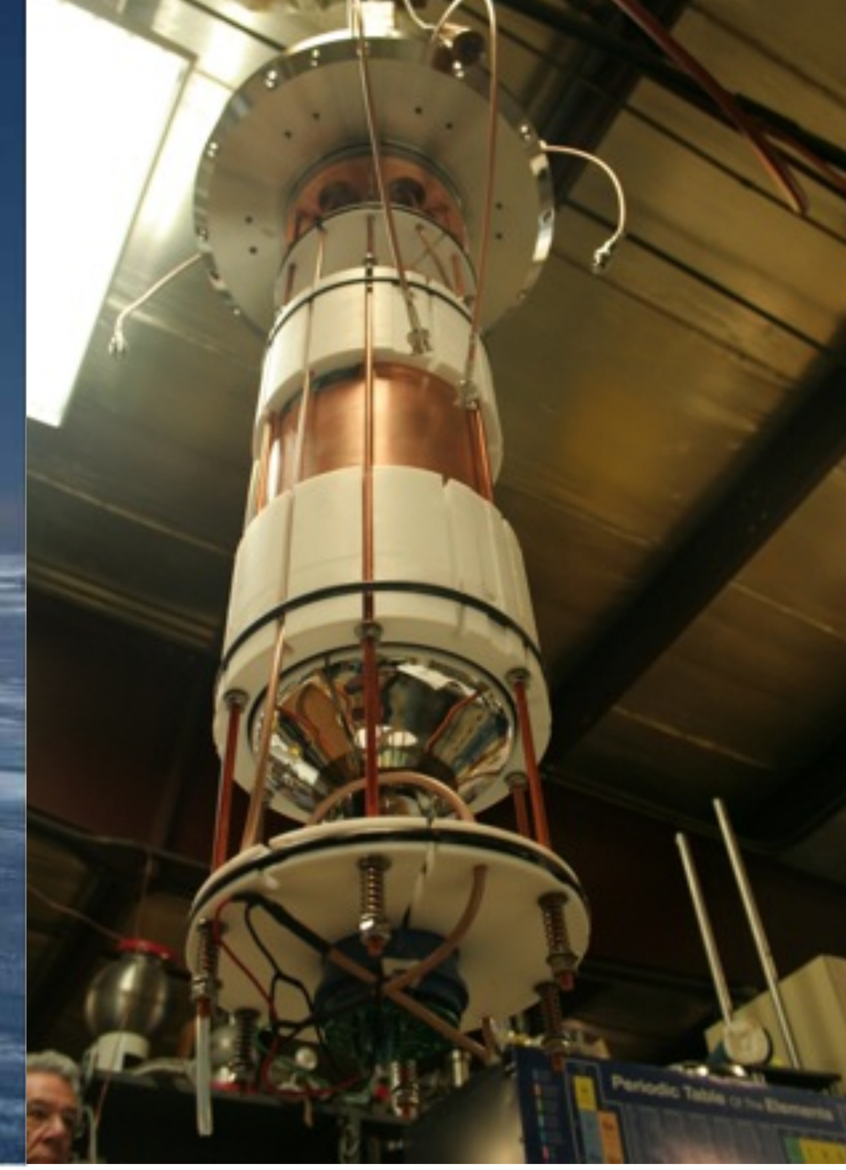



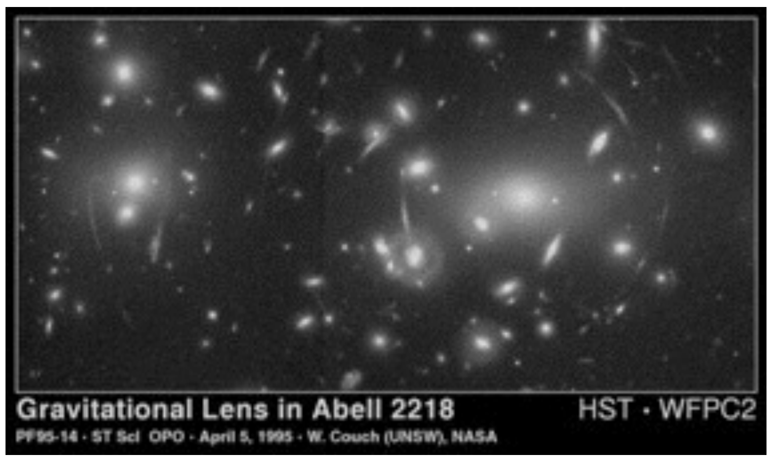
# First Data and Prospects for DM-Ice

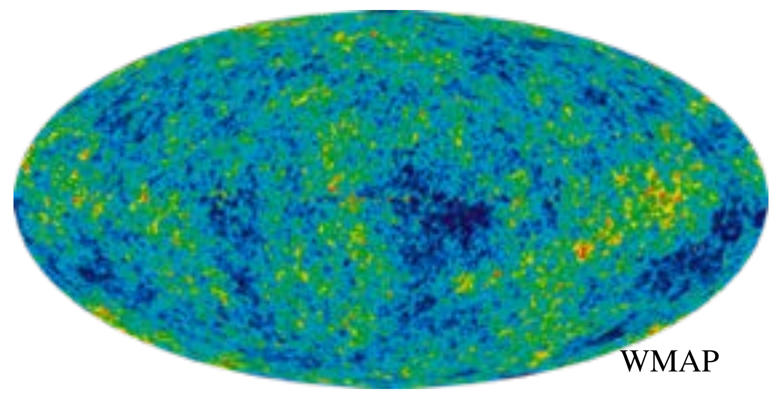
**Reina Maruyama**
**Yale University**

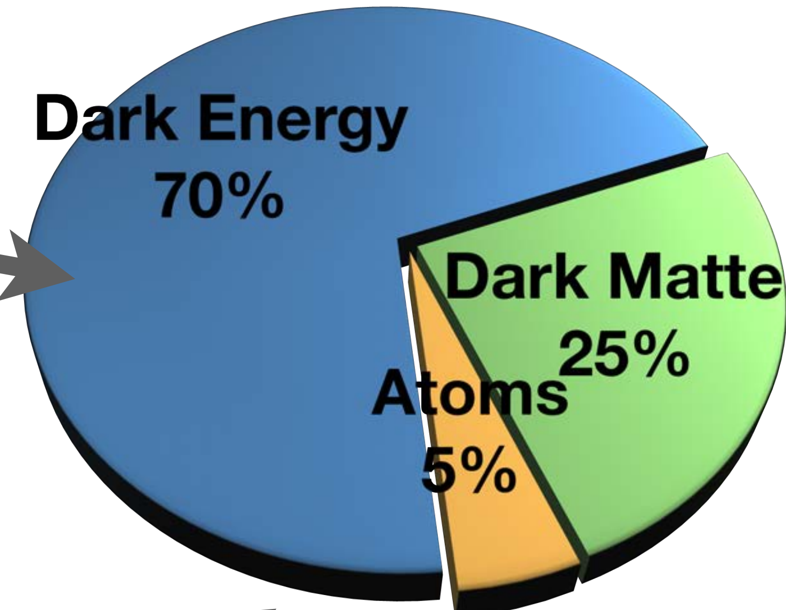
**INFN / Dip. di Fisica - "Sapienza" Università di Roma**
**Particle Physics Seminar**
**May 12, 2014**

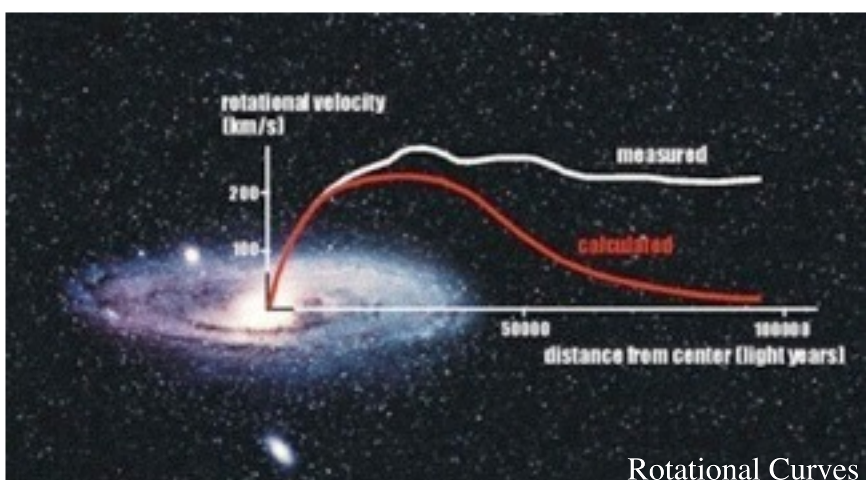
# Evidence for Dark Matter

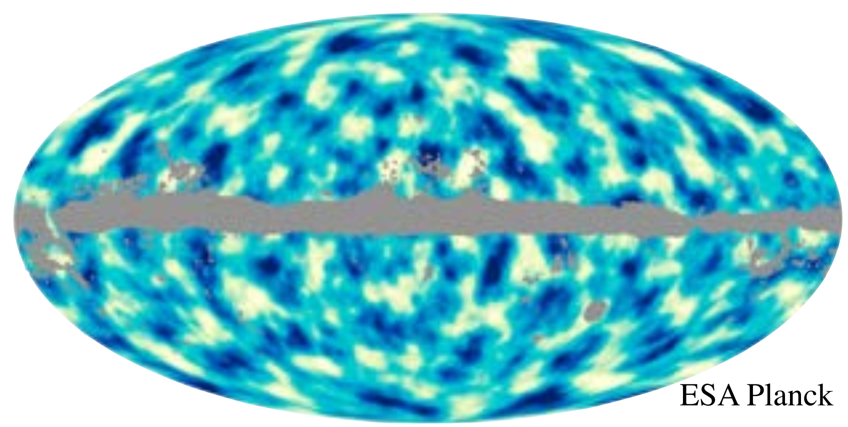
- Many gravitational evidence for dark matter

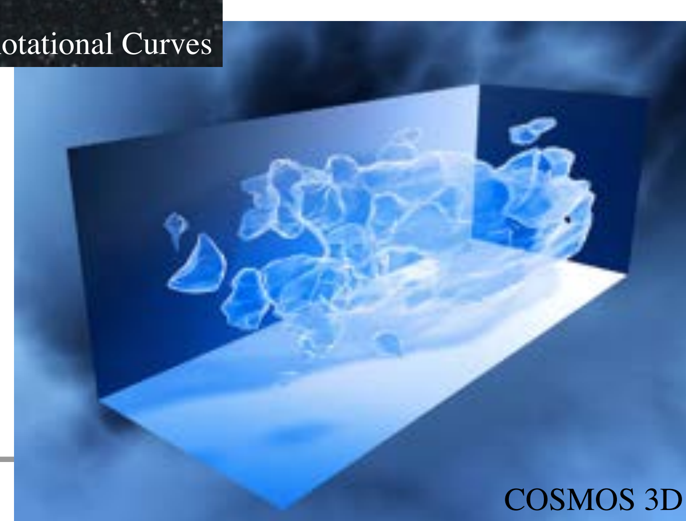



All consistent with ~25% dark matter (give or take).

**But... what is it?**

# What is Dark Matter?

## Leading Candidates:

**Axions**

- mass ~$10^{-3} – 10^{-6}$ eV
- Arises in the Peccei-Quinn solution to the strong-CP problem

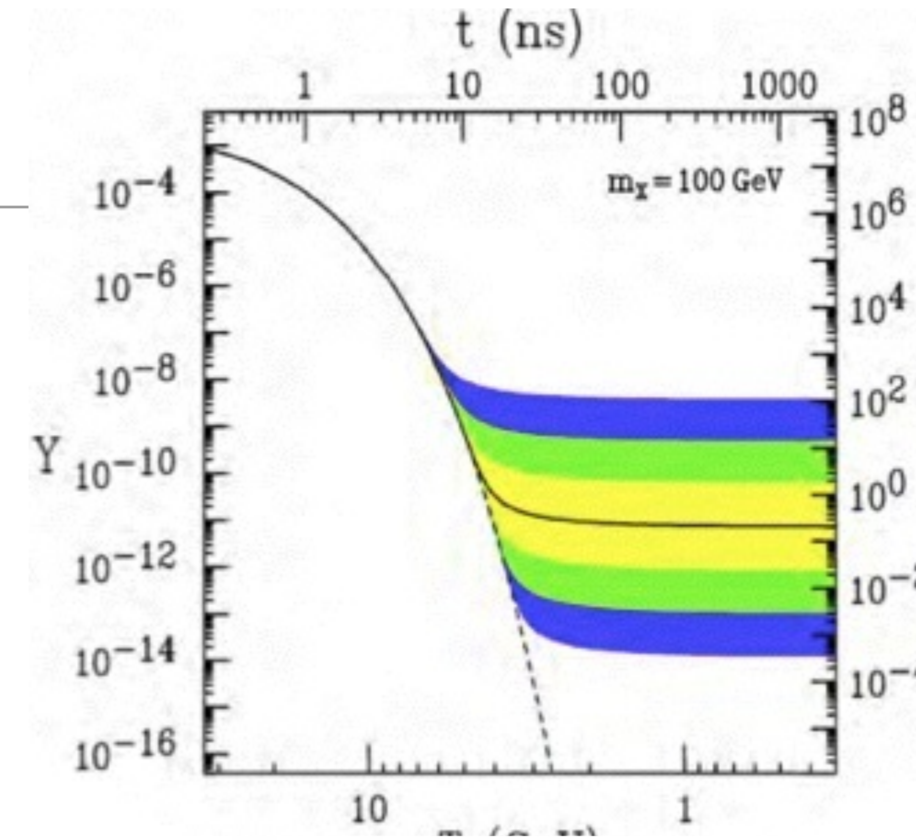
**WIMPs: Weakly Interacting Massive Particles**

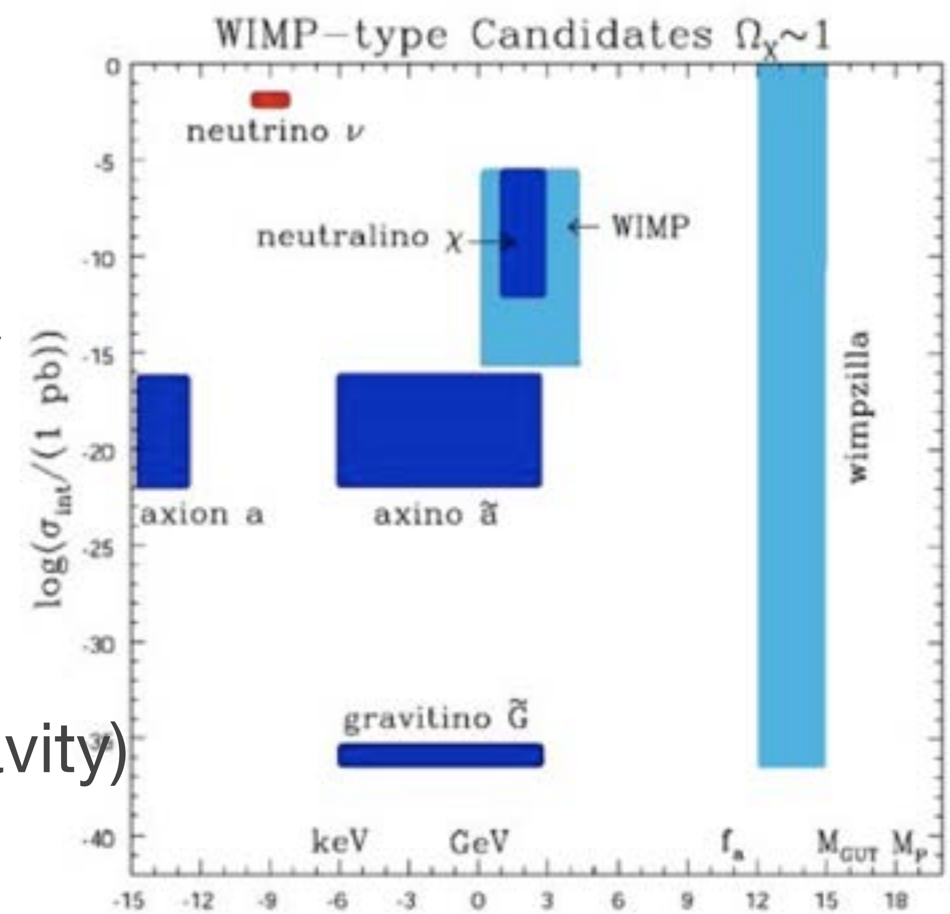
- mass of 1 GeV – 10 TeV
- weak scale cross sections results in observed abundance

$$\sigma \approx 10^{-39} - 10^{-46}\ \mathrm{cm}^2$$

$$\langle \sigma_A v \rangle \approx 10^{-26}\ \mathrm{cm}^3/\mathrm{s}$$

$$m_\chi \approx 100\ \mathrm{GeV}$$



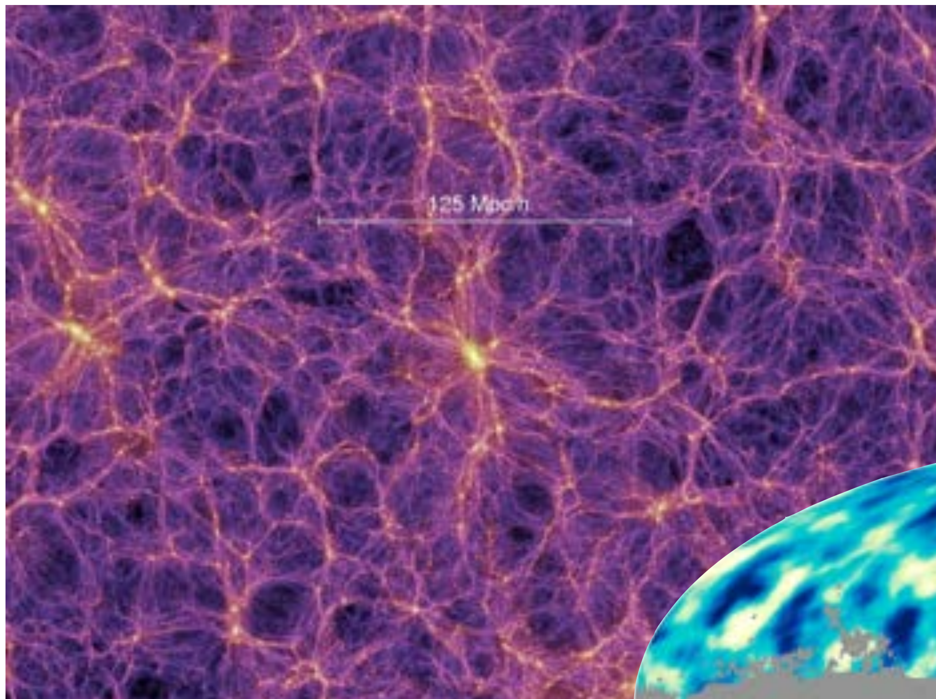




(Roszkowski 2004)

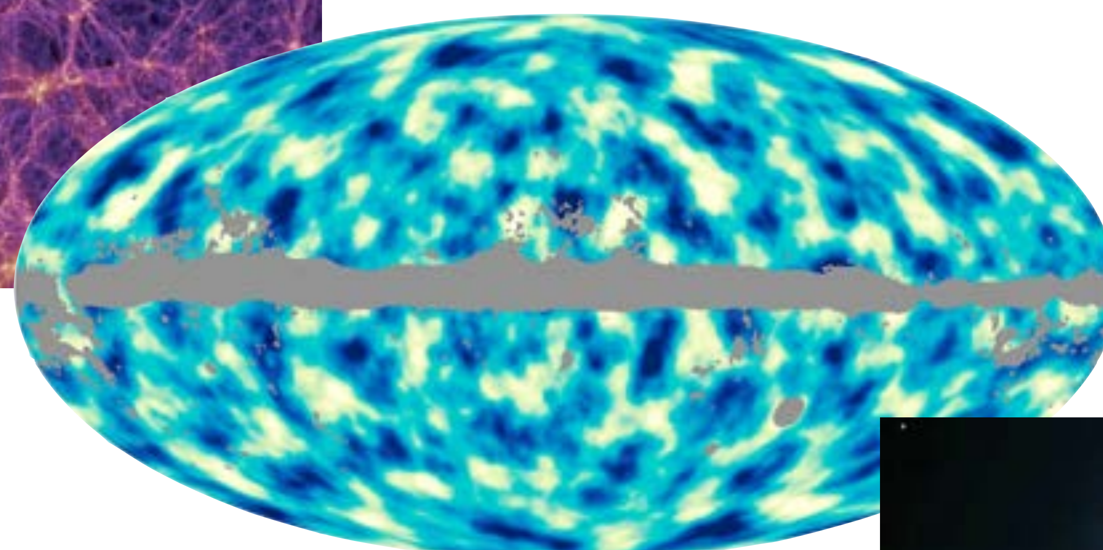
## Observational evidence indicates:

- Non-baryonic
- Cold and massive (non-relativistic and exerts gravity)
- Interact little with ordinary matter
- Stable and long-lived

# Dark Matter Distribution



Large scale dark matter distribution
Millenium Simulation
http://www.mpa-garching.mpg.de/galform/virgo/millennium/



Planck all-sky image of the distribution of dark matter via distortions on CMB by gravitational lensing (April 2013)

Artist's impression of the Milky Way galaxy. The blue halo of material surrounding the galaxy indicates the expected distribution of dark matter. (ESO/Calçada)

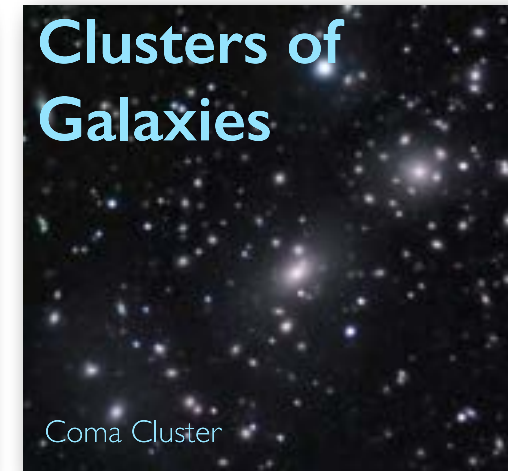
# Regions Dense in Dark Matter


small halo model dependence, boost factors


Large DM content, nearby source, O(10) larger flux than extra-galactic


Very dense DM accumulation, nearby source


no astrophysical backgrounds




large DM content, high boost factors from sub structure

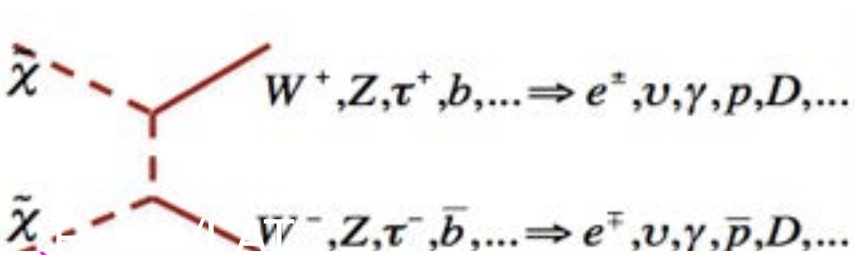
# Detecting WIMPs

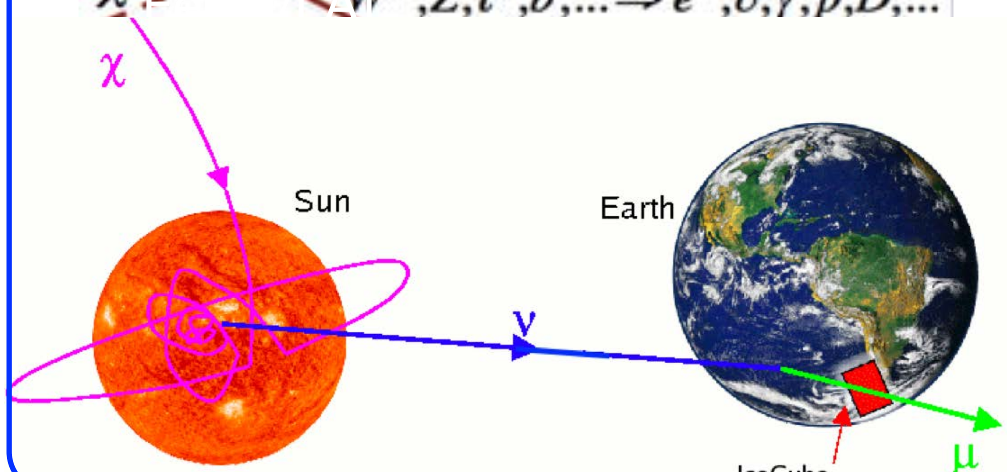
## annihilation

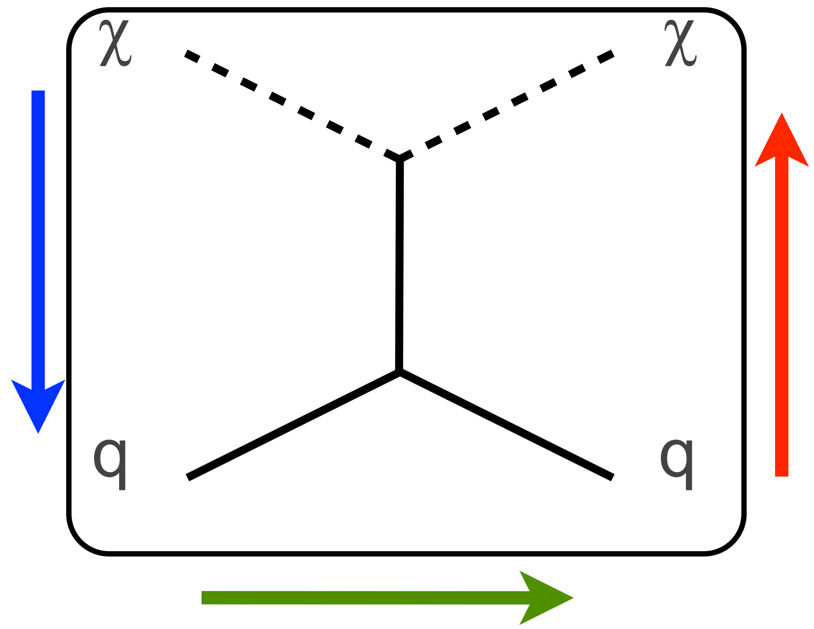
**"Indirect Detection"**

Collect dark matter in Stars and Galaxies, then let them annihilate among themselves.

Detect the decay particles



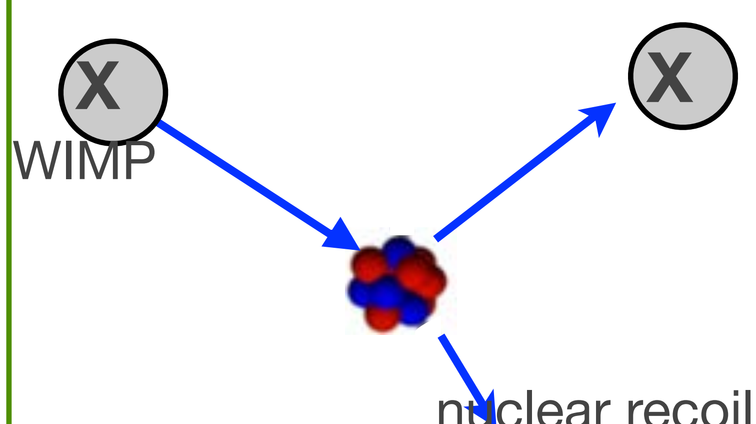




## scattering

**"Direct Detection"**

Let dark matter recoil off of nuclei

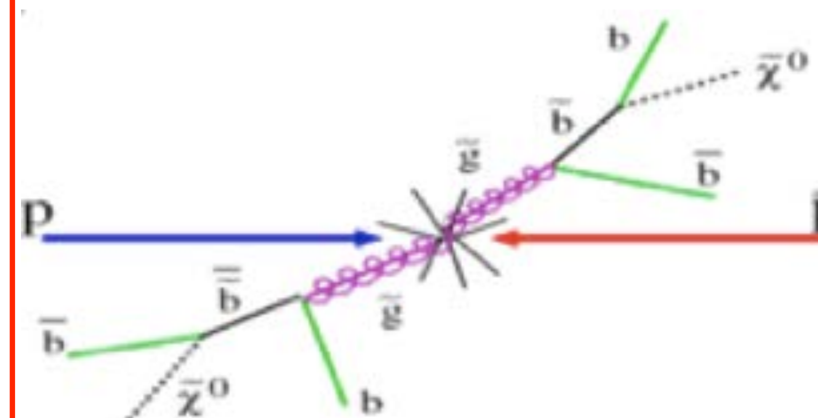
Look for nuclear recoil

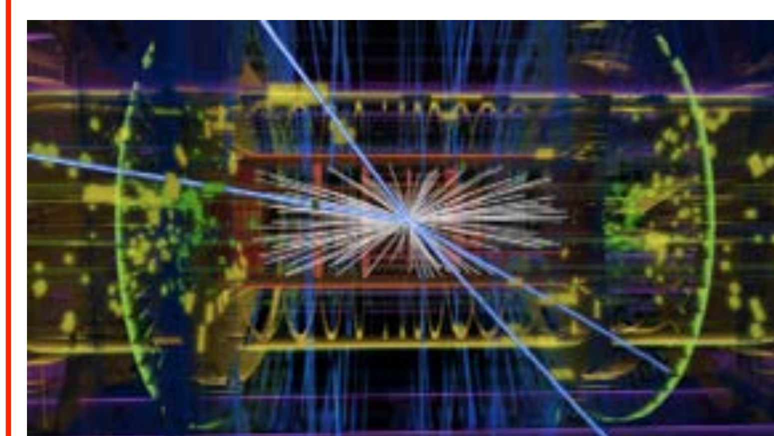



## production

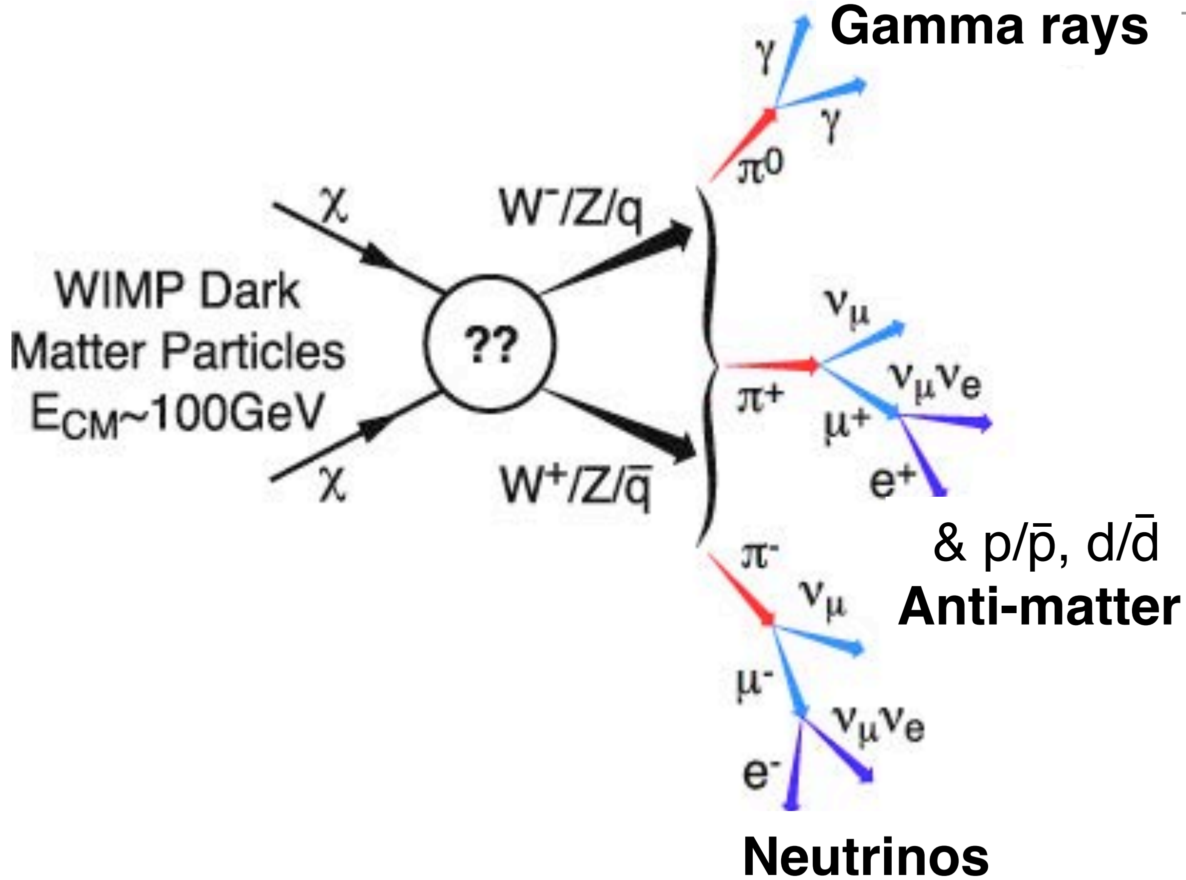
**Colliders**

Look for the missing energy



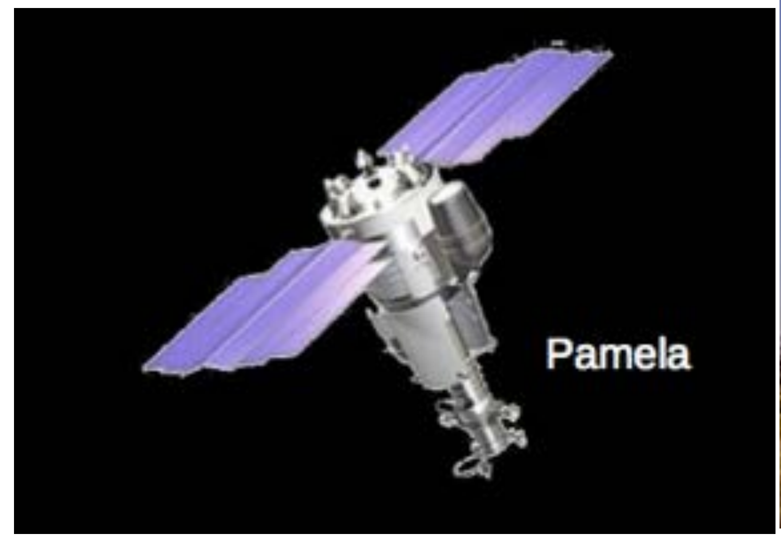



# Current Detectors: Annihilation signals



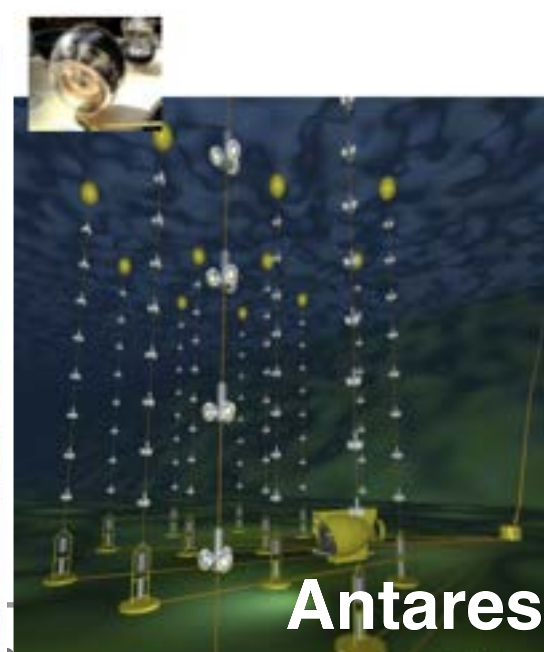

## Cherenkov telescopes & satellites



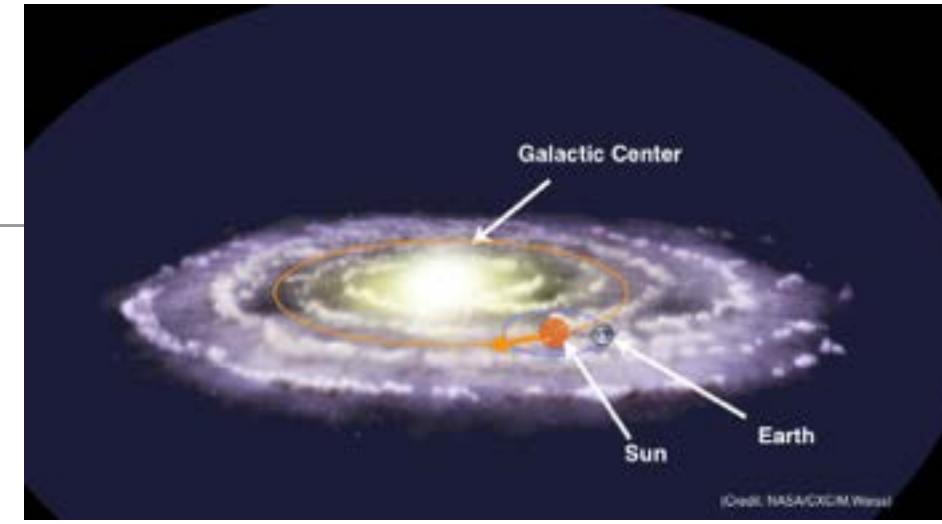




## Neutrino Telescopes

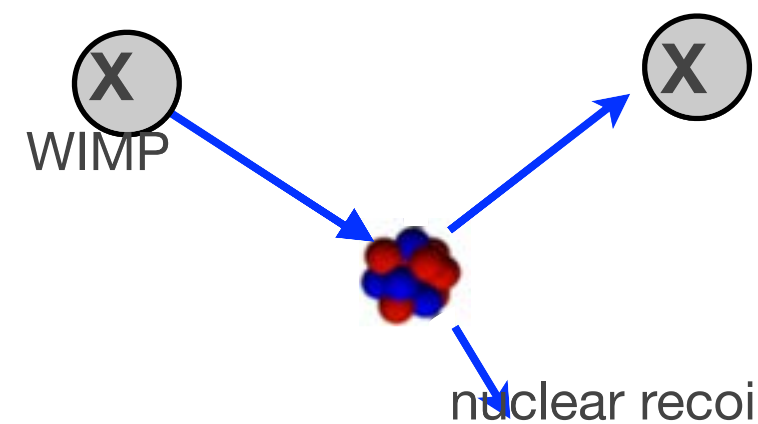

# Direct Detection of WIMPs




- naively... WIMPs elastically scatter off nuclei in targets, producing nuclear recoils

Interaction Rate:

$$R \propto N \frac{\sigma_{\chi N}}{m_\chi} \rho_\chi \int_{v_{min}}^{v_{esc}} \frac{f(v)dv}{v}$$




Nuclear/Particle Physics

$\sigma_{SI} \sim \sigma_0 A^2 |F(q)|^2$

$v_{min}$ : detector threshold

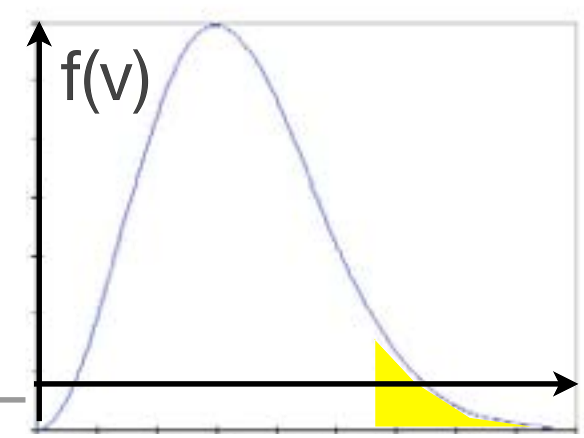
Astrophysics

WIMP distribution in the galaxy

$\rho_0 = 0.3$ GeV/cm$^3$

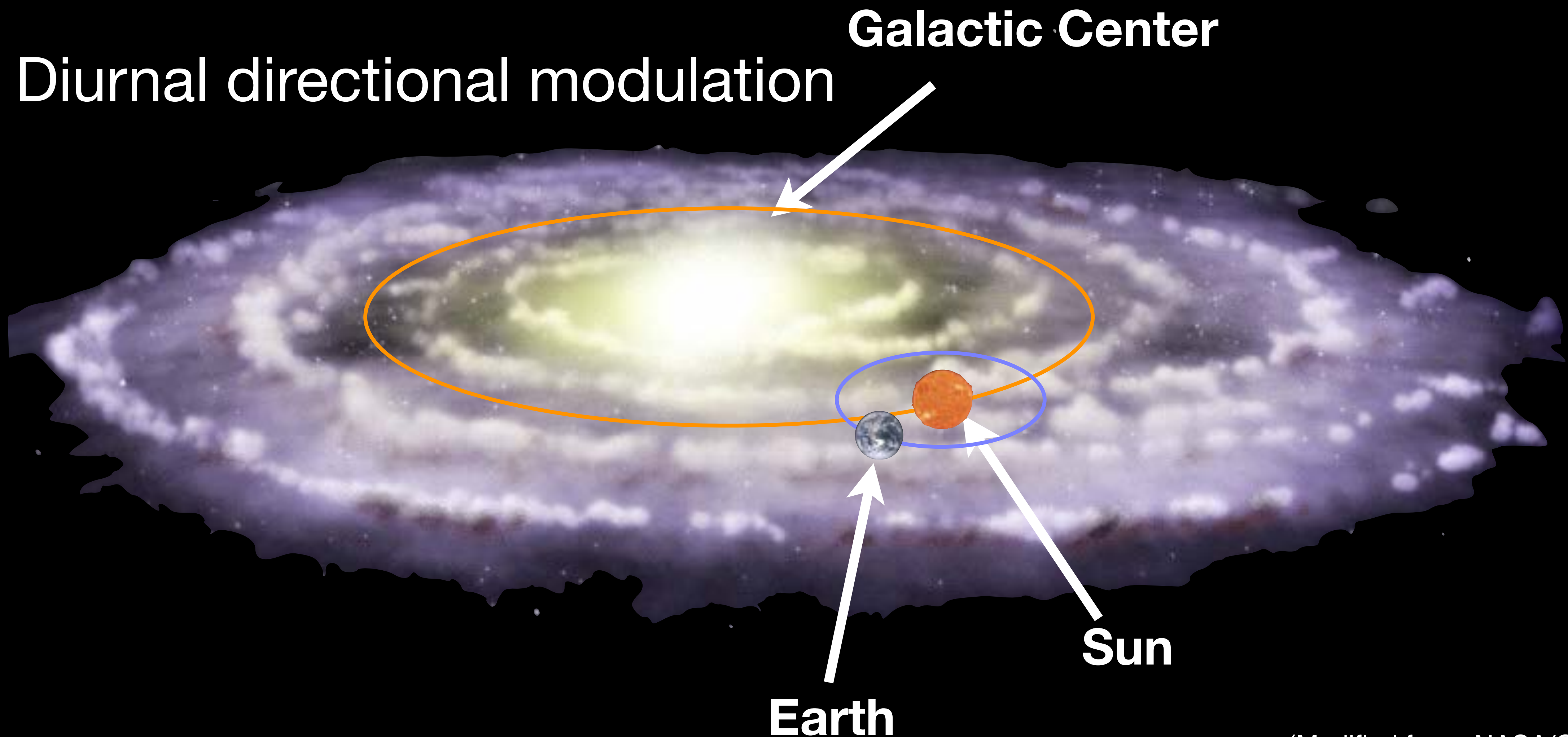
$v_{rms} \approx 270$ km/s

$v_{max} \approx 550$ km/s



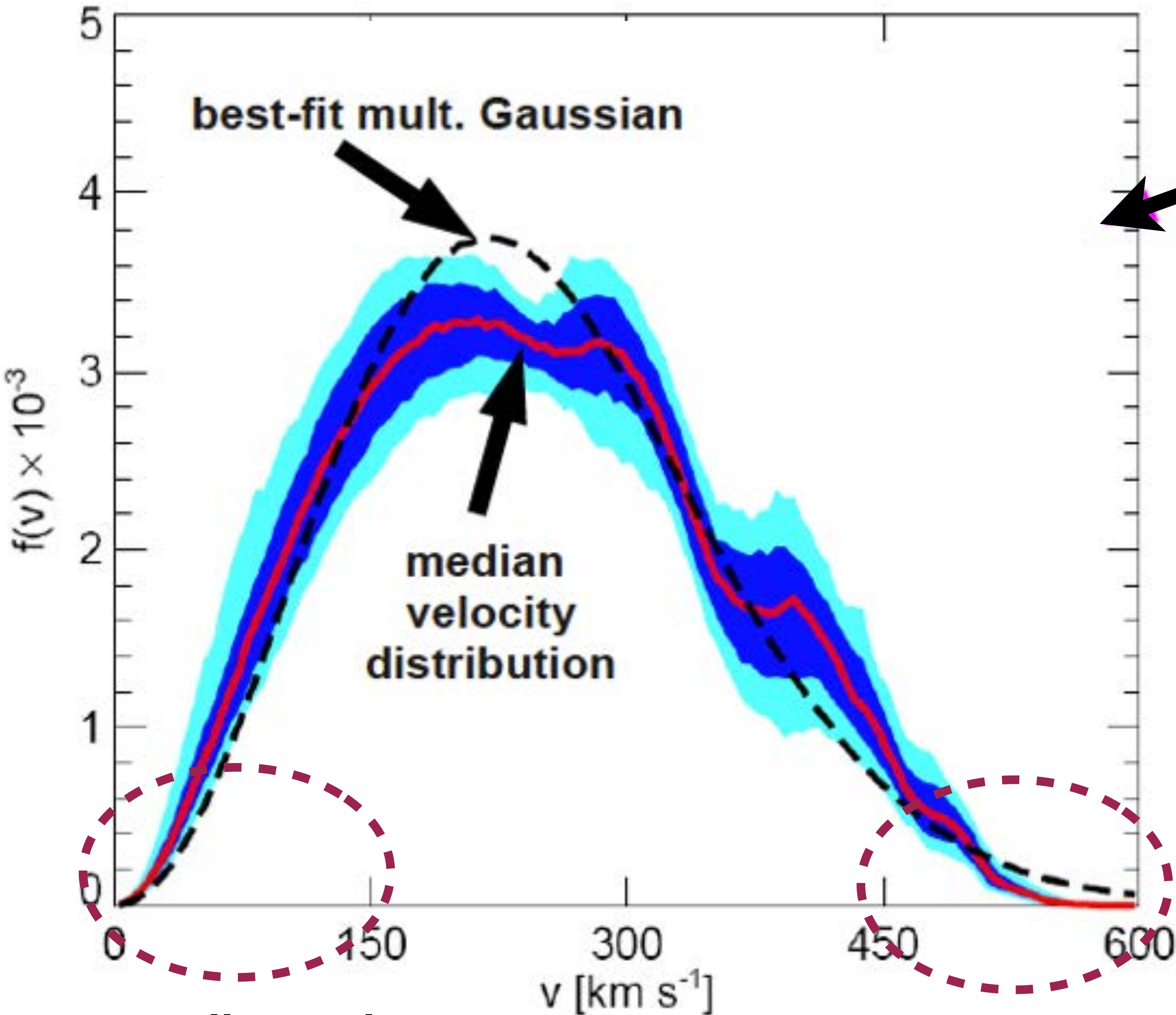
# Direct Detection Search Strategies

1. Count individual nuclear recoils
2. Look for annual modulation
3. Diurnal directional modulation




(Modified from: NASA/CXC/M.Weiss)

# Local Dark Matter Density / Velocity




small recoils
"easiest" to be captured in the Sun/Earth - indirect searches

large recoils
"best sensitivity" with direct detection

Maxwellian is reasonable

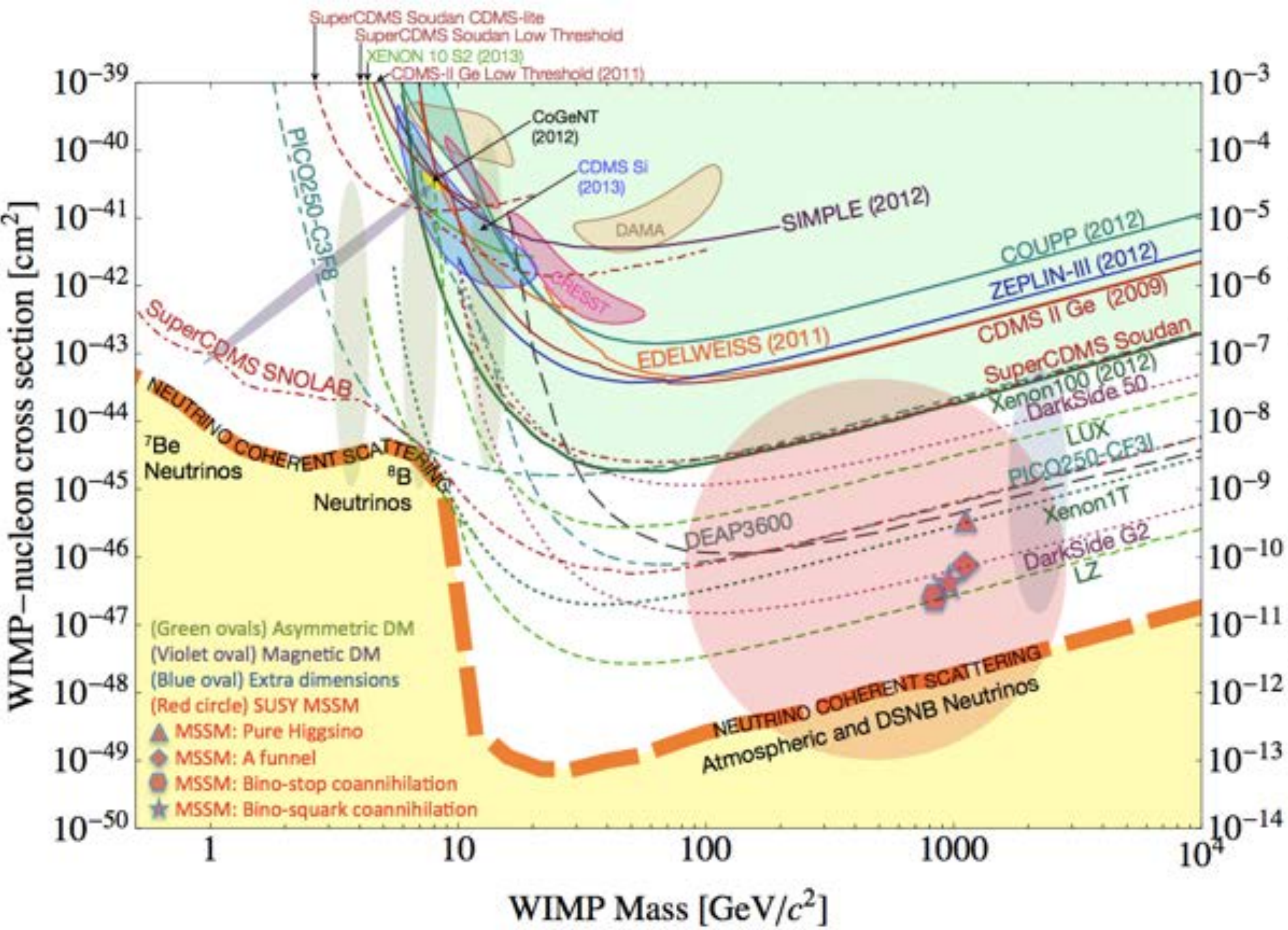
Velocity distribution still not very well understood

Local dark matter density
~0.3GeV/cm$^3$

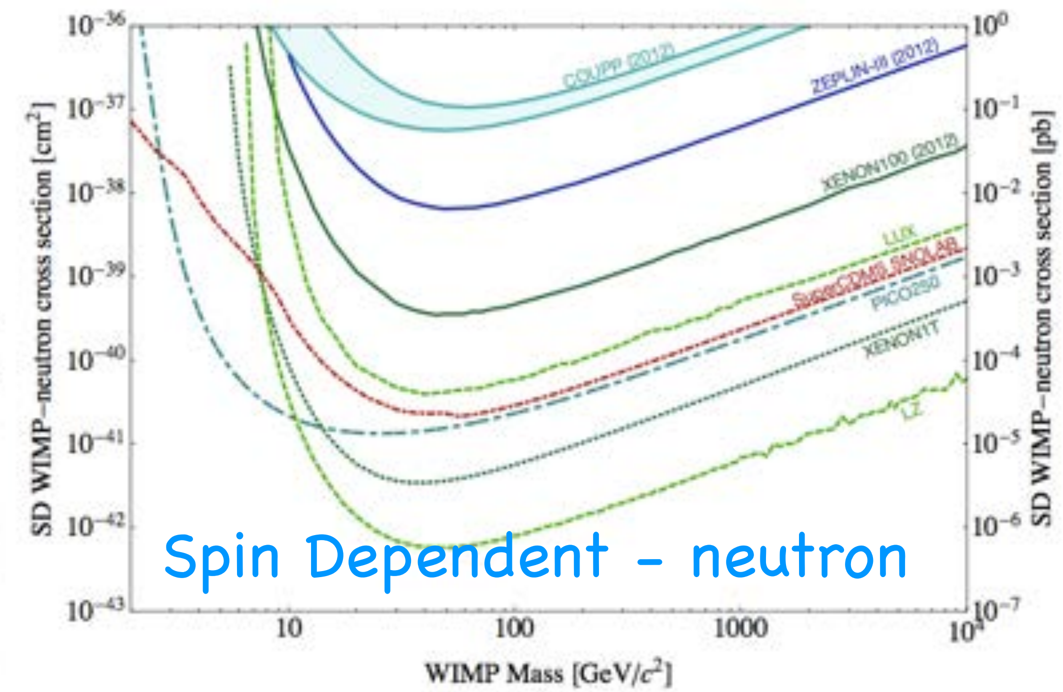
# Direct Detection Experiments


Laura Baudis
DM Overview
Neutrino 2012

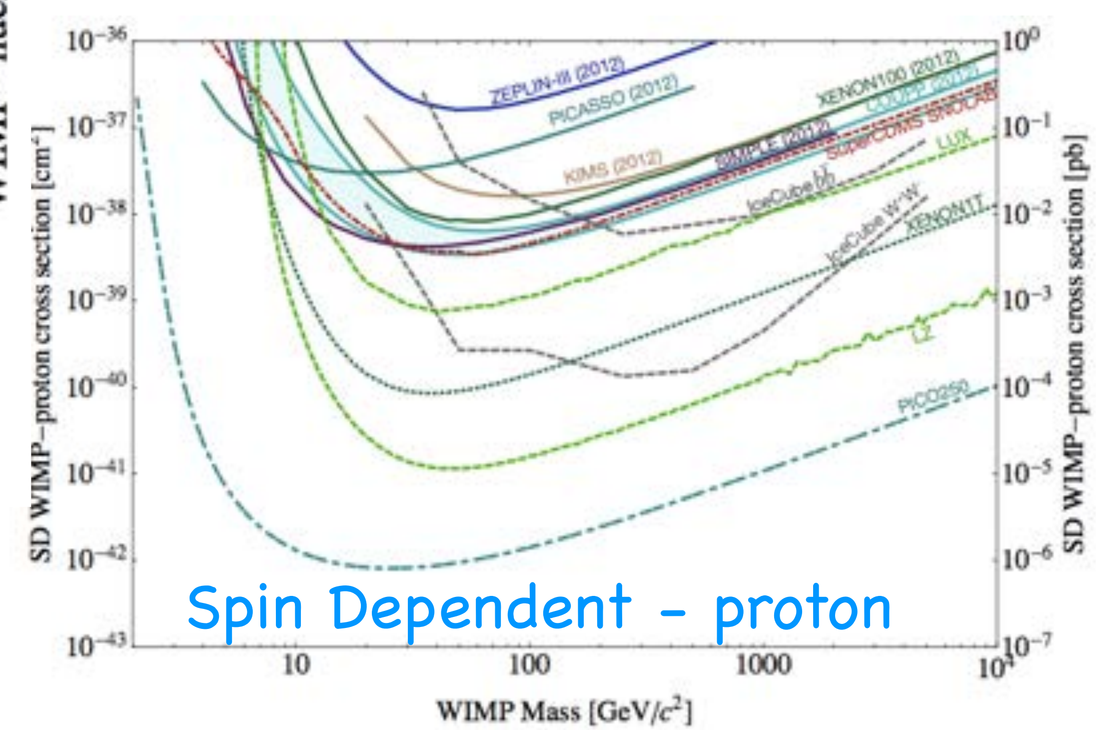
# Direct Detection, Current and Future




Spin Independent WIMP-nucleon cross section



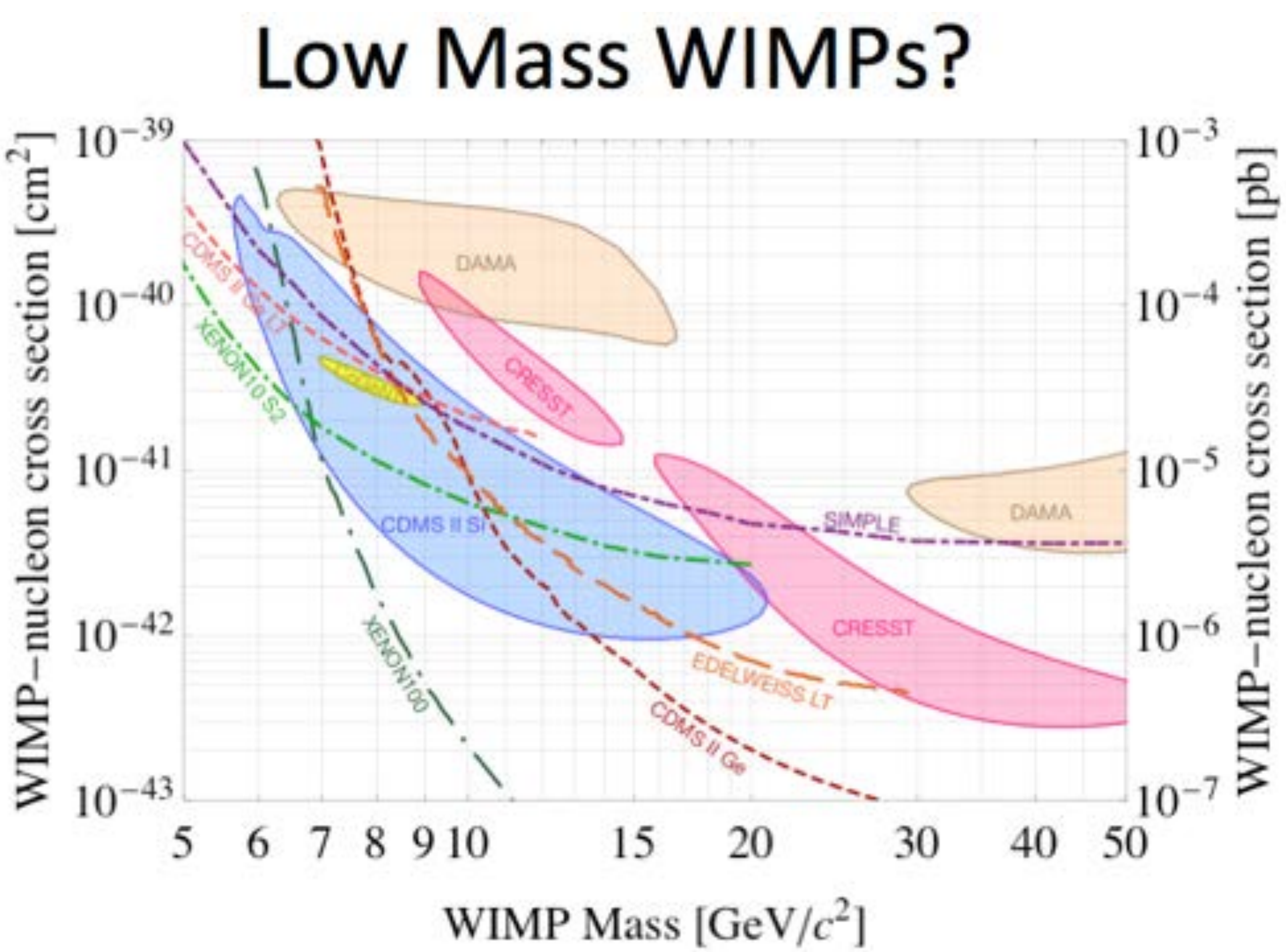

Spin Dependent - neutron



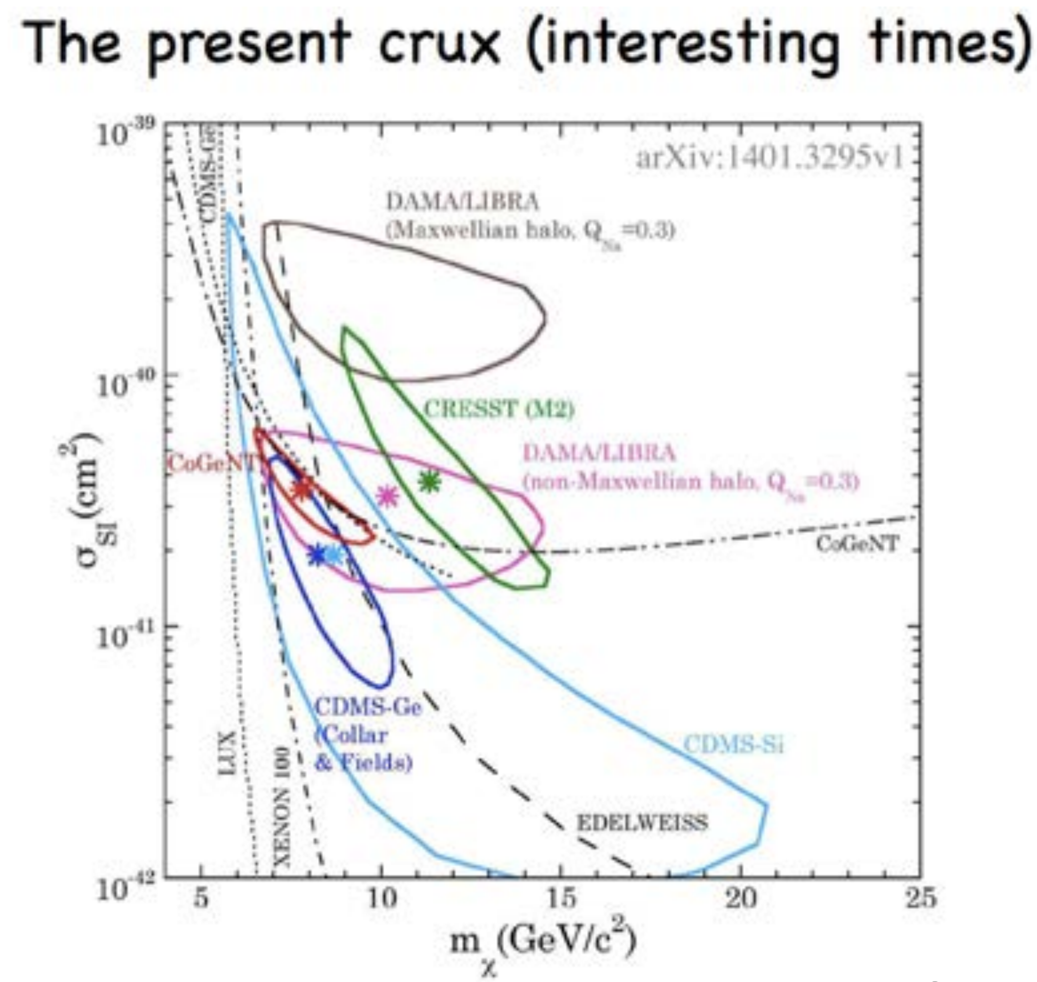

Spin Dependent - proton

SNOWMASS 2013: arXiv:1310.8327

# Hints and Claims for Direct Detection of DM




SNOWMASS 2013: arXiv:1310.8327



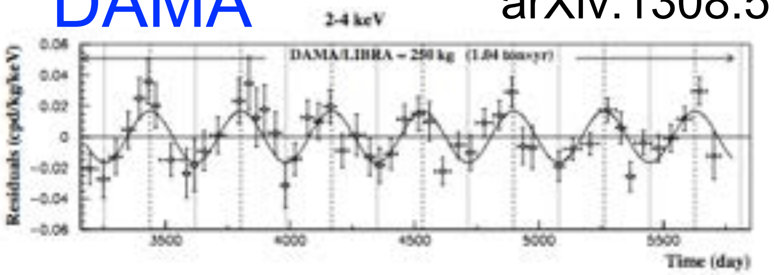

Juan Collar,
arXiv:1401.3295

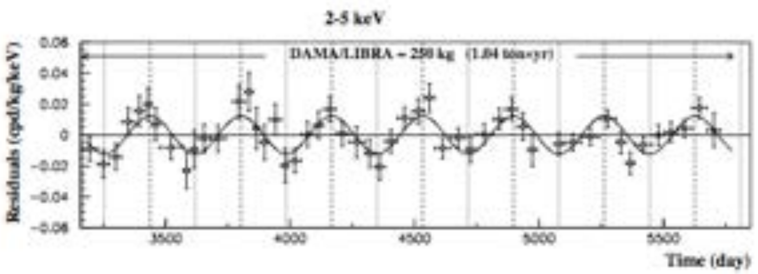
**Challenges:** Astrophysics, Particle Physics, & Instrumental Effects

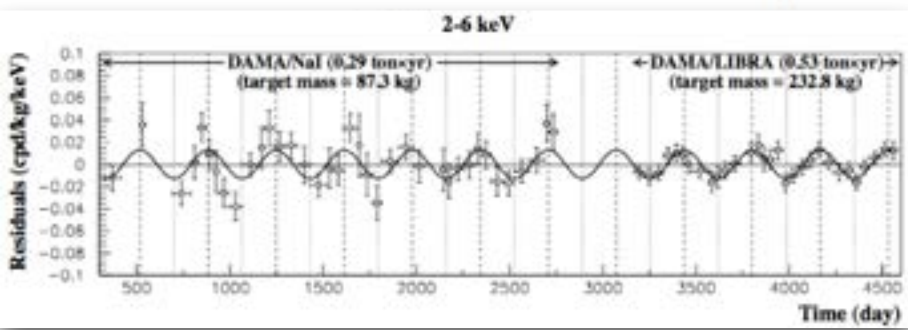
# Dark Matter Signal or Background?

DAMA

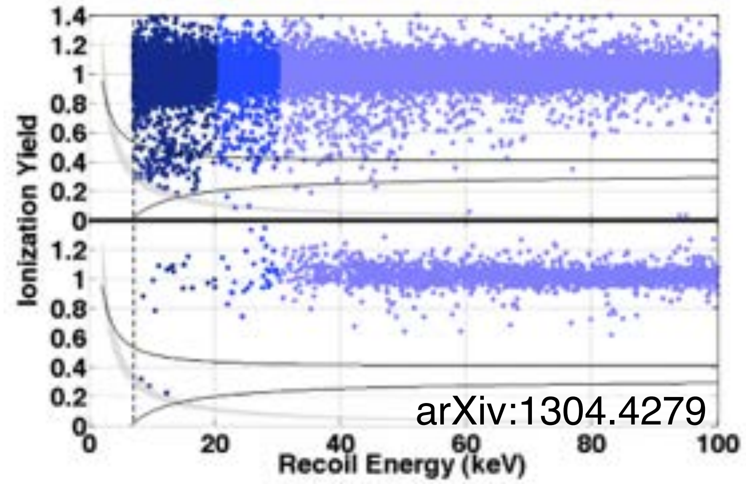
arXiv:1308.5109



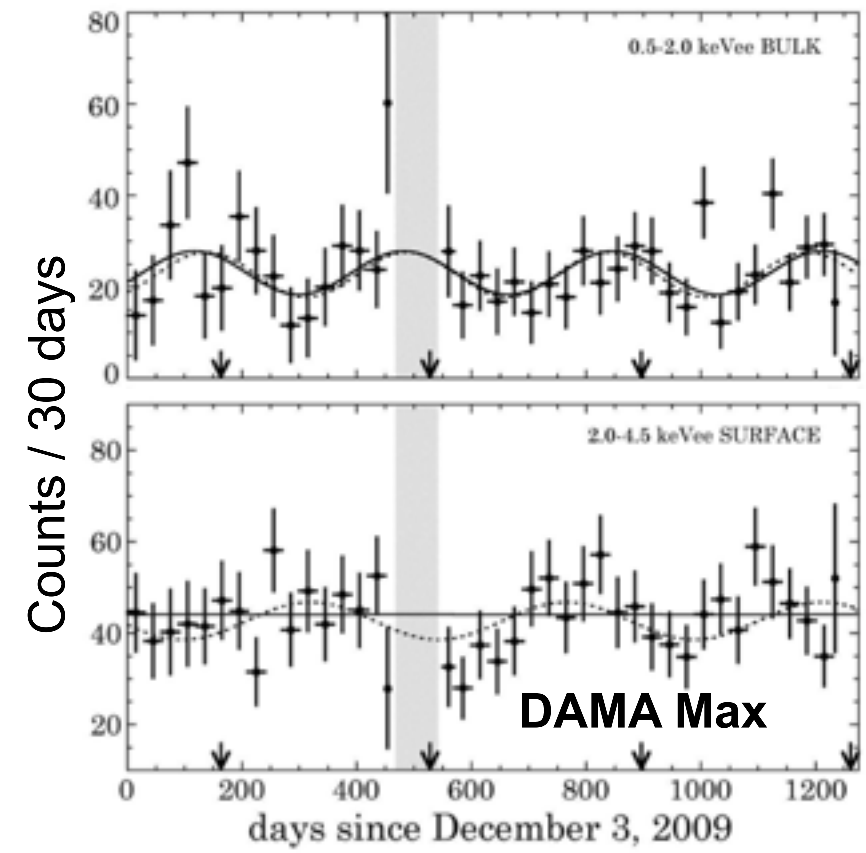



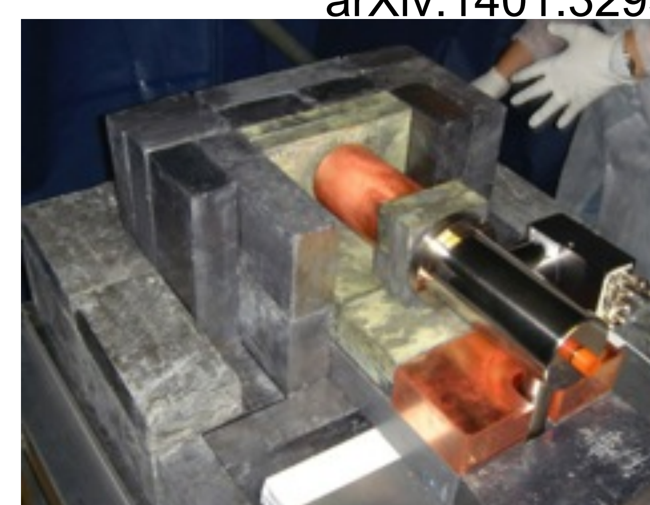

CDMS-Si



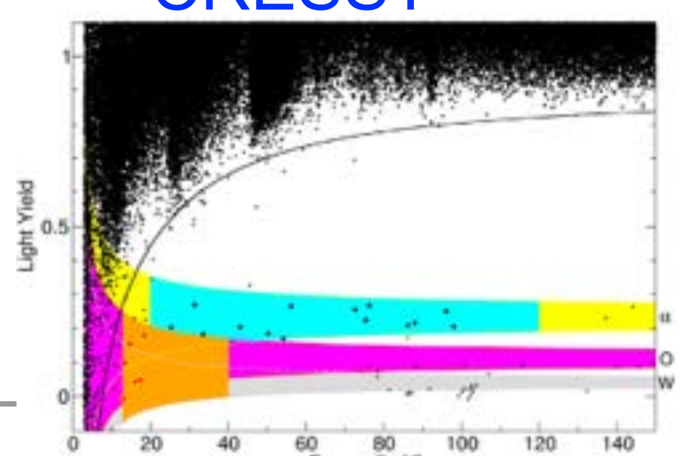

CoGeNT




arXiv:1401.3295

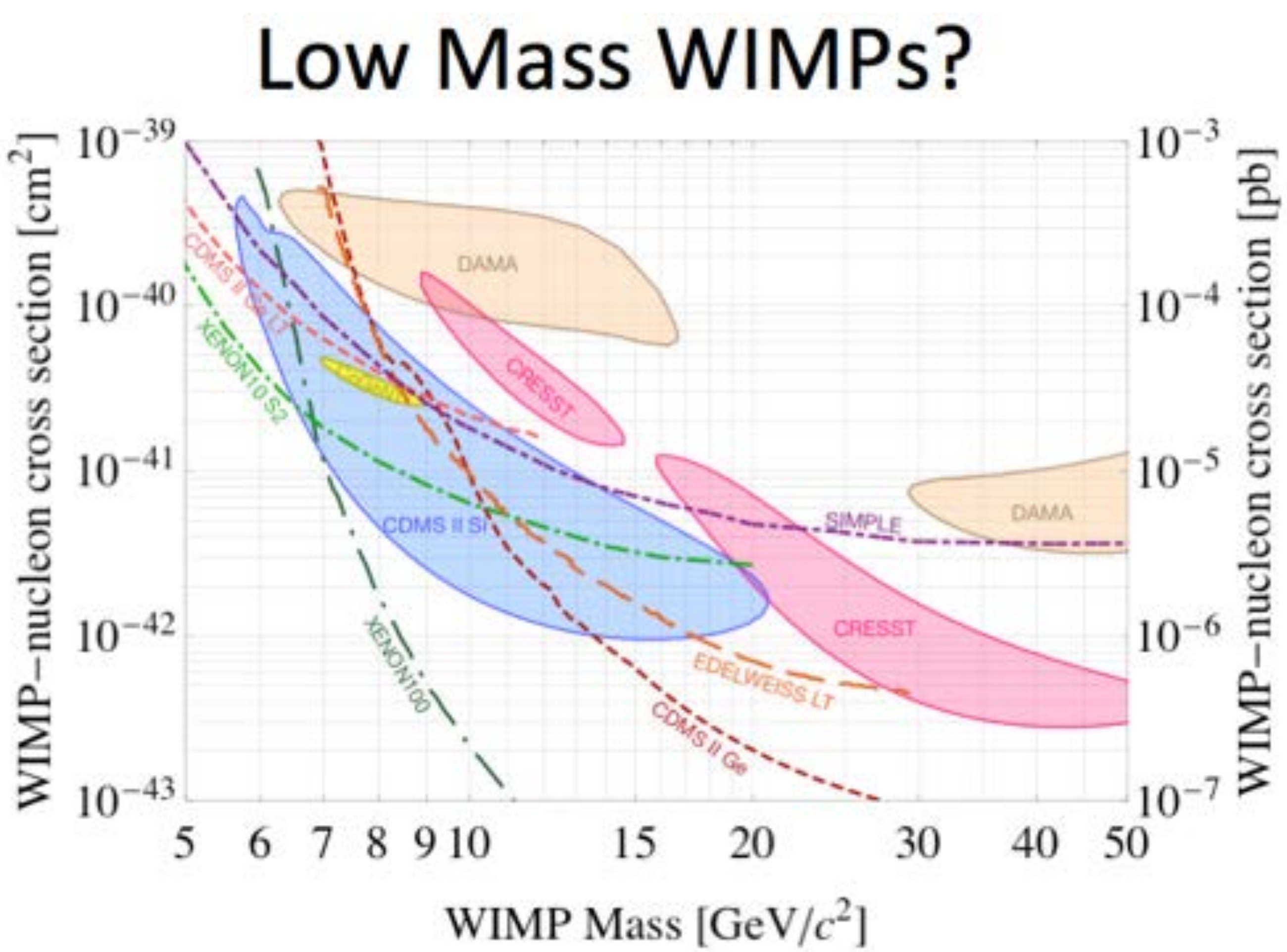


CRESST

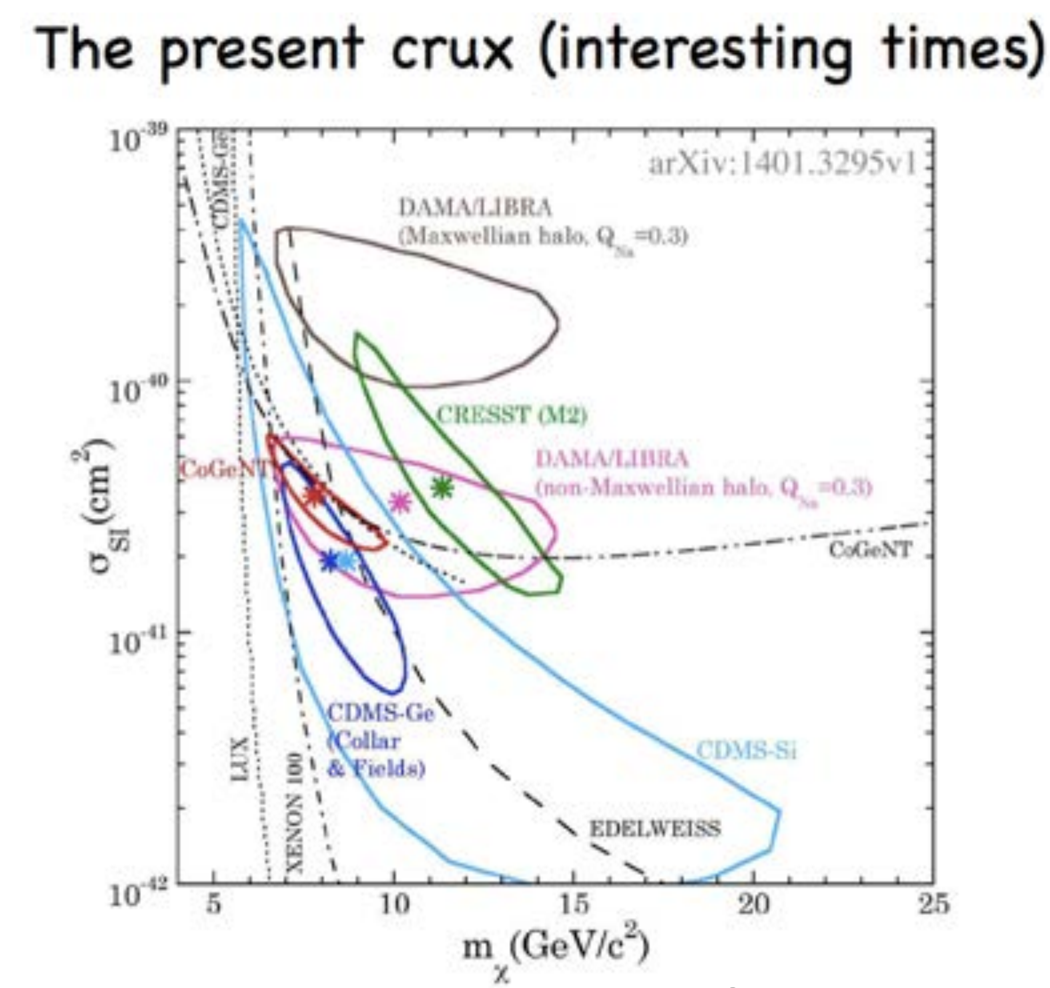



Eur. Phys. J. C (2012) 72:1971

# Hints and Claims for Direct Detection of DM




SNOWMASS 2013: arXiv:1310.8327




Juan Collar, LLWI 2014
arXiv:1401.3295

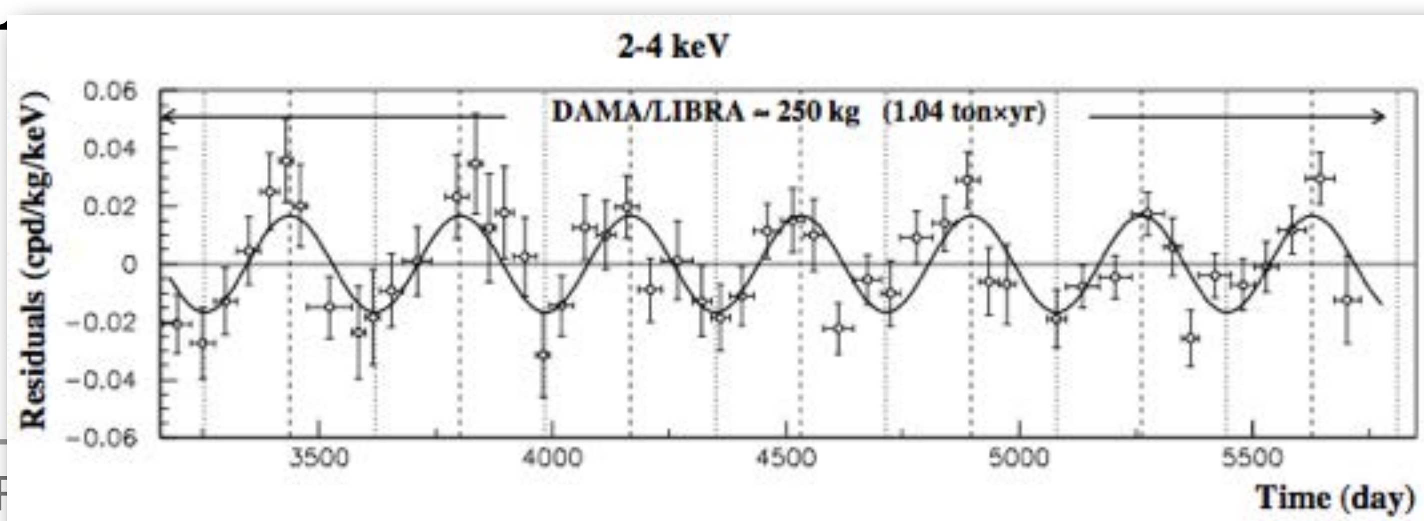
**Challenges:** Astrophysics, Particle Physics, & Instrumental Effects

**Solution: Repeat the same experiment with same detector medium, but with better handle on background(s)**

# Modulation Observed by DAMA

Longest standing and the largest signal: **9.3 σ modulation over 14 years**
(no sign of it going away)

- Modulation consistent with dark matter:
  - **Phase:** 144 ± 7 days (peak on May 24)
  - **Period:** 0.998 ± 0.002 yr
  - **Background:** ~ 1 cnts/keV/kg/day
  - **Amplitude:** 0.0112 ± 0.0012 cnts/keV/kg/day
- Two generations:
  - DAMA/NaI: 100 kg (1996 - 2003)
  - DAMA/LIBRA-phase1: 250 kg (2003 - 2010)

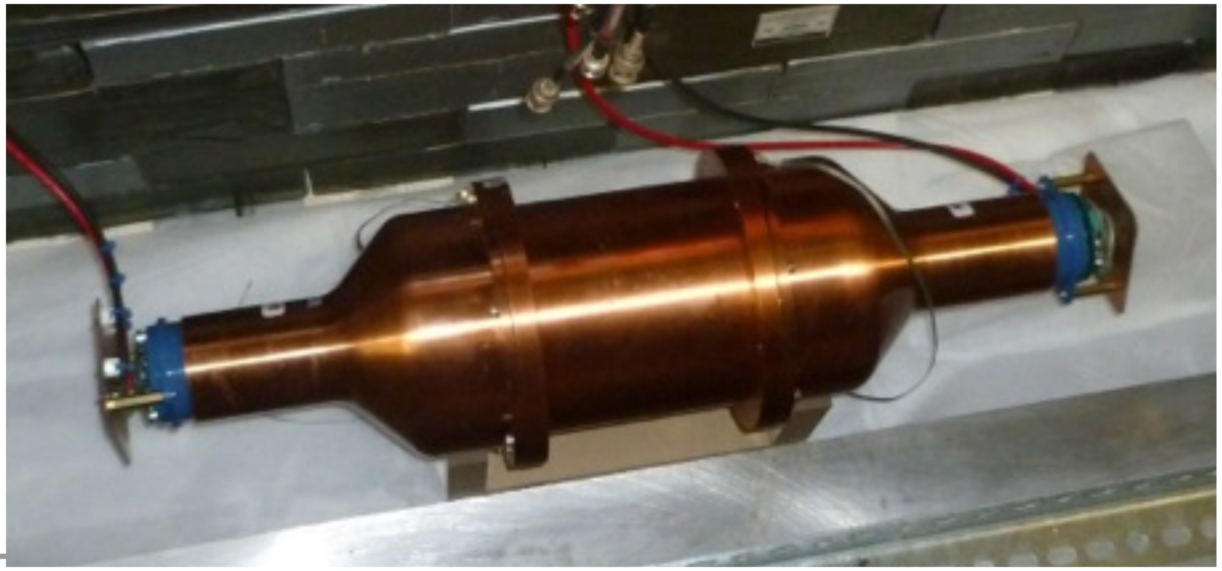



**but is it dark matter?**

arxiv:1308.5109

# NaI Detectors for Direct Dark Matter Detection

- **Detector**: NaI scintillating crystals + Photomultiplier tubes
- **Scintillation signal only**
  - Discrimination between nuclear recoil versus electron recoil possible only at higher energies via pulse shape
  - At energy region of interest (2 - 10 keV), PS discrimination not possible.
- **To achieve low threshold, we need:**
  - require coincidence between two PMTs to eliminate PMT noise
  - two PMTs also help with light collection
  - ultra-pure NaI crystals + shielding for low background
- **Stable environment:** DAMA's claim relies solely on the observation of at the annual modulation with the correct phase.

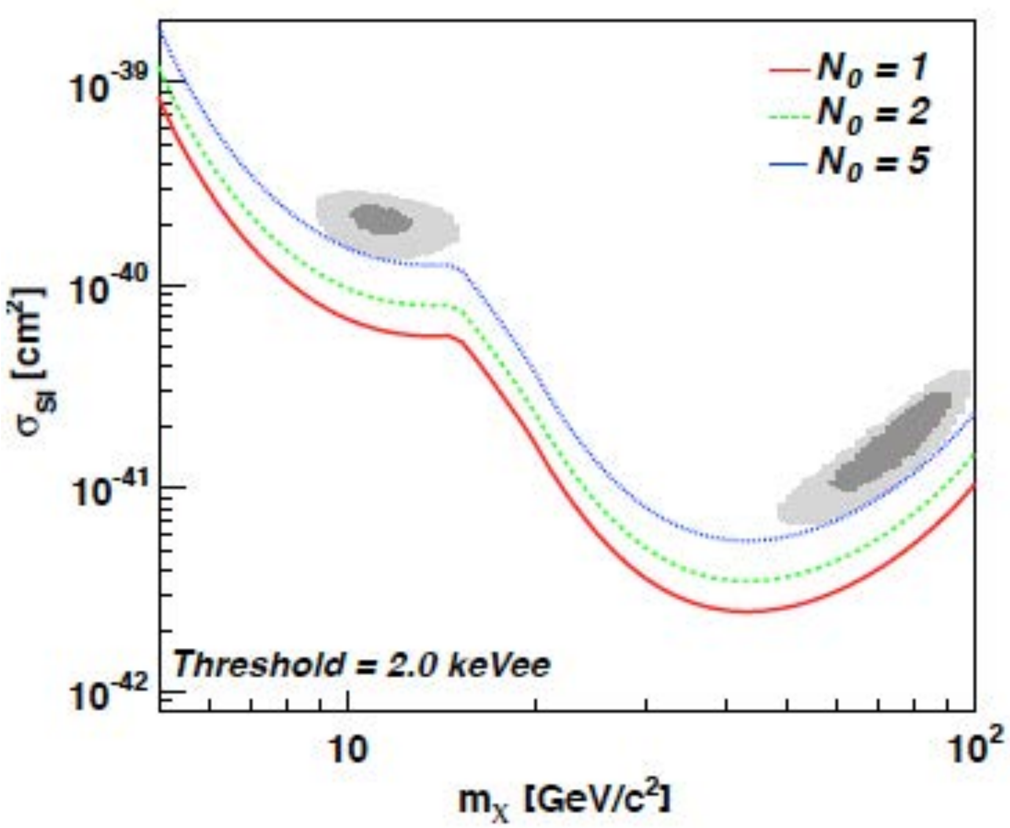


# Testing DAMA's Dark Matter Claim

Definitive (5σ) detection or exclusion with

arXiv:1106.1156

- 500 kg-yr NaI(Tl) (DAMA x 2 yrs)
- same or lower threshold (< 2 $keV_{ee}$)
- background < (DAMA  x 5)




**500 kg·year NaI detector sensitivity**

(2 - 4 keV) with bgd of 1, 2, and 5 cnts/keV/kg/day.

| | Years | DM-Ice17<br>17.0 kg | NAIAD-scale<br>44.5 kg | DAMA-scale<br>250 kg |
|---|---|---|---|---|
| x8 DAMA background | 1 | 0.45 | 0.72 | 1.71 |
| | 3 | 0.77 | 1.25 | 2.96 |
| | 5 | 1.00 | 1.61 | 3.82 |
| | 7 | 1.18 | 1.91 | 4.52 |
| x4 DAMA background | 1 | 0.63 | 1.02 | 2.42 |
| | 3 | 1.09 | 1.77 | 4.18 |
| | 5 | 1.41 | 2.28 | 5.40 |
| | 7 | 1.67 | 2.70 | 6.39 |
| Double DAMA background | 1 | 0.85 | 1.37 | 3.26 |
| | 3 | 1.47 | 2.38 | 5.64 |
| | 5 | 1.90 | 3.07 | 7.29 |
| | 7 | 2.25 | 3.64 | 8.62 |
| DAMA background | 1 | 1.20 | 1.94 | 4.61 |
| | 3 | 2.08 | 3.37 | 7.98 |
| | 5 | 2.69 | 4.35 | 10.31 |
| | 7 | 3.18 | 5.14 | 12.19 |
| 1/10 DAMA background | 1 | 3.80 | 6.15 | 14.57 |
| | 3 | 6.58 | 10.65 | 25.24 |
| | 5 | 8.50 | 13.75 | 32.59 |
| | 7 | 10.06 | 16.27 | 38.56 |

**Additional Information by lowering the threshold below 2 keV.**

# Annual Modulation Dark Matter Searches with NaI Detectors

| | | | | |
|---|---|---|---|---|
| **Northern Hemisphere** | Gran Sasso<br>**DAMA/Libra**<br>250kg<br>running | Gran Sasso<br>**SaBRE**<br>R&D | Canfranc<br>**ANAIS**<br>250 kg<br>starting in 2014? | **PICO-LON**<br>**KIMS**<br>etc... |
| **Southern Hemisphere** | South Pole<br>**DM-Ice**<br>17 kg running<br>R&D for 250 kg | | | ice rock |

Several Groups conducting ultra-pure crystal with several vendors to go to the full scale

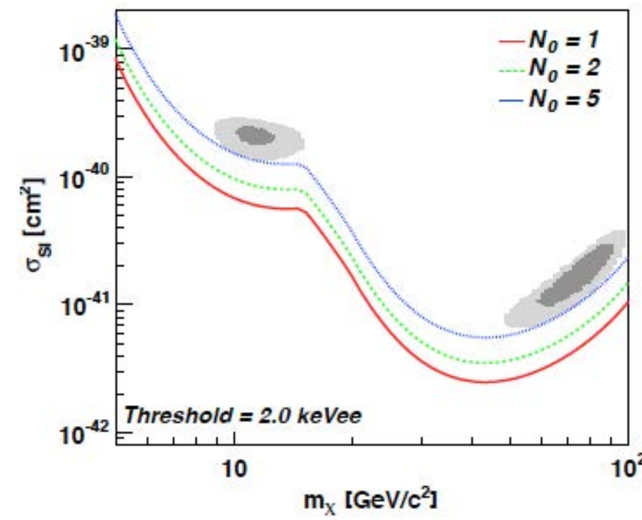
**DM-Ice:**

- NaI dark matter search in an entirely different environment
- South Pole offers:
  - Ultra-clean and ultra-stable environment
  - Seasonal variation unambiguously different from dark matter modulation
  - IceCube offers muon monitoring and veto as well as experience
  - NSF-run South Pole Station for logistical support

# Phased Program for DM-Ice

## Directly test DAMA's assertion that the observed annual modulation is due to dark matter & understand its origin

- probes longest-standing dark matter claim
- NaI(Tl) target
- aims to understand origin of DAMA's signal
- only experiment with access to both Northern & Southern Hemispheres




**500 kg•years**
(2 - 4 keV) with 1, 2, and 5 dru background

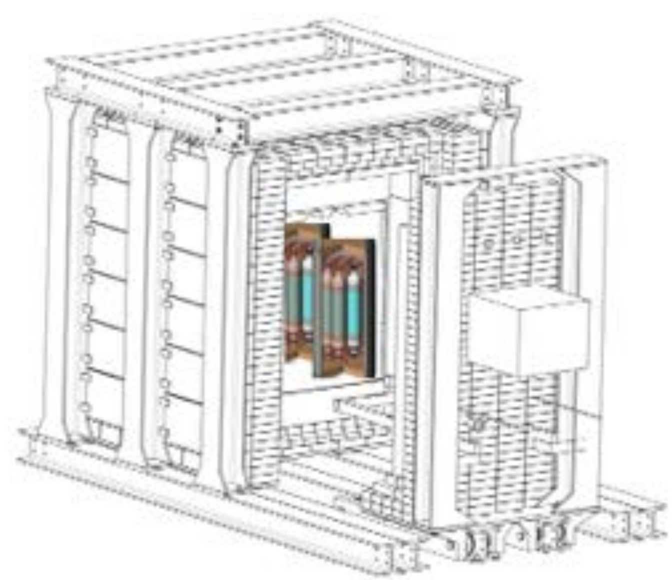
Astropart.Phys. 35 (2012) 749-754

## A Phased Experimental Program

### DM-Ice17

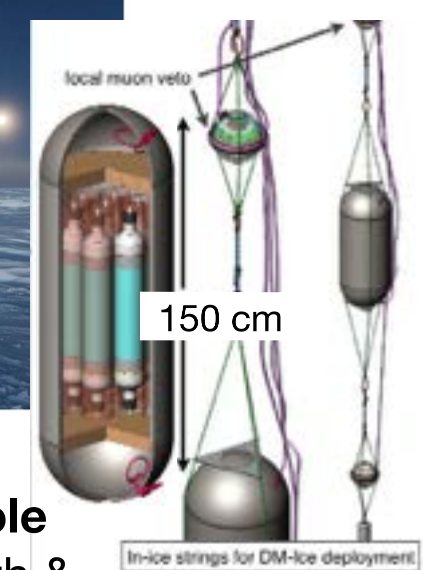
**Operating since 2011**
17 kg of NaI(Tl) at 2450m depth at South Pole

### DM-Ice 250 North



**Northern Hemisphere Run**
portable 250 kg NaI(Tl) detector, first deployment in the Northern Hemisphere

### DM-Ice 250 South




**Deployment at South Pole**
if modulation seen in North & ice drilling becomes available

# DM-Ice17

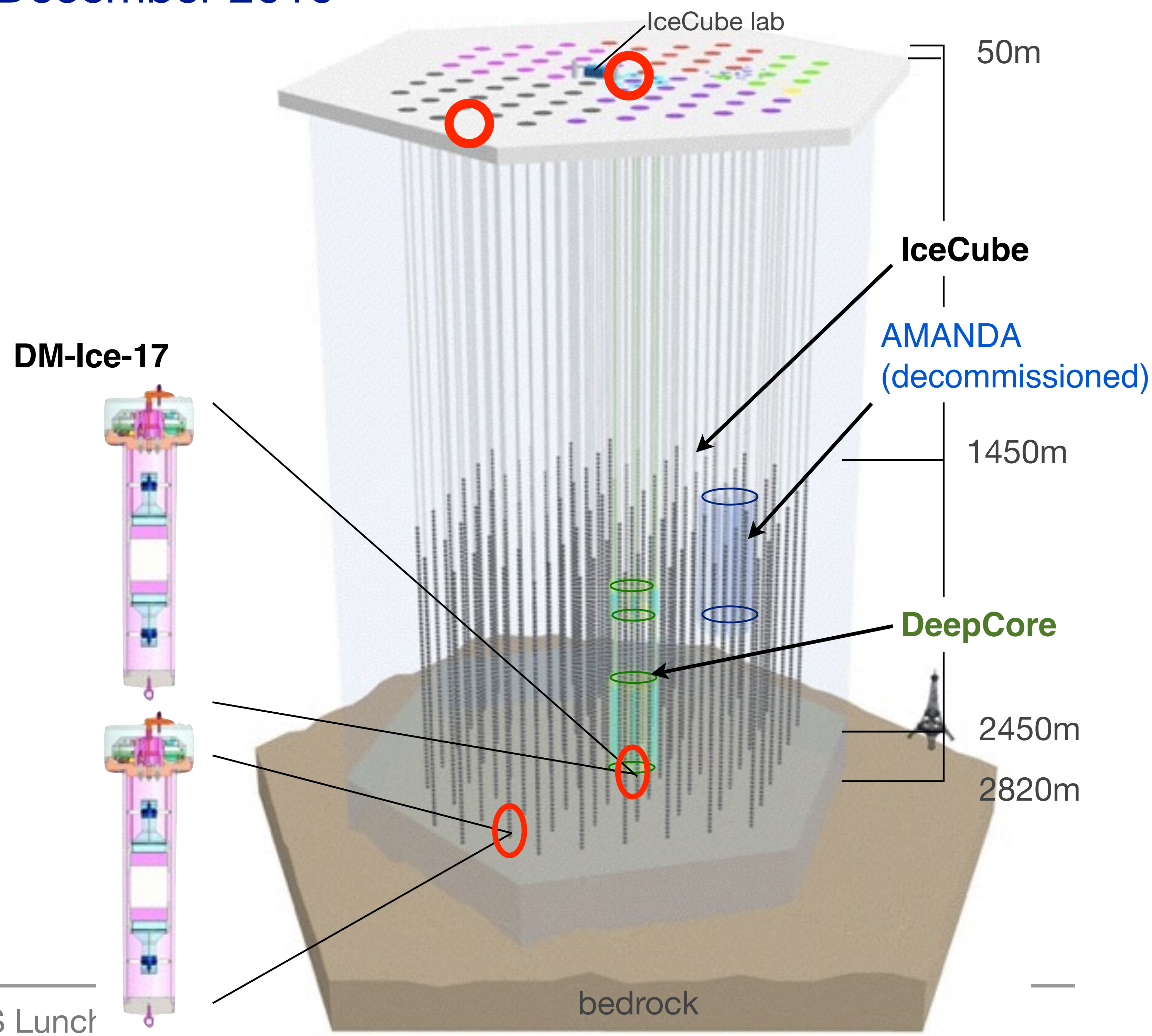
# Prototype: DM-Ice-17

Deployed at the South Pole in December 2010

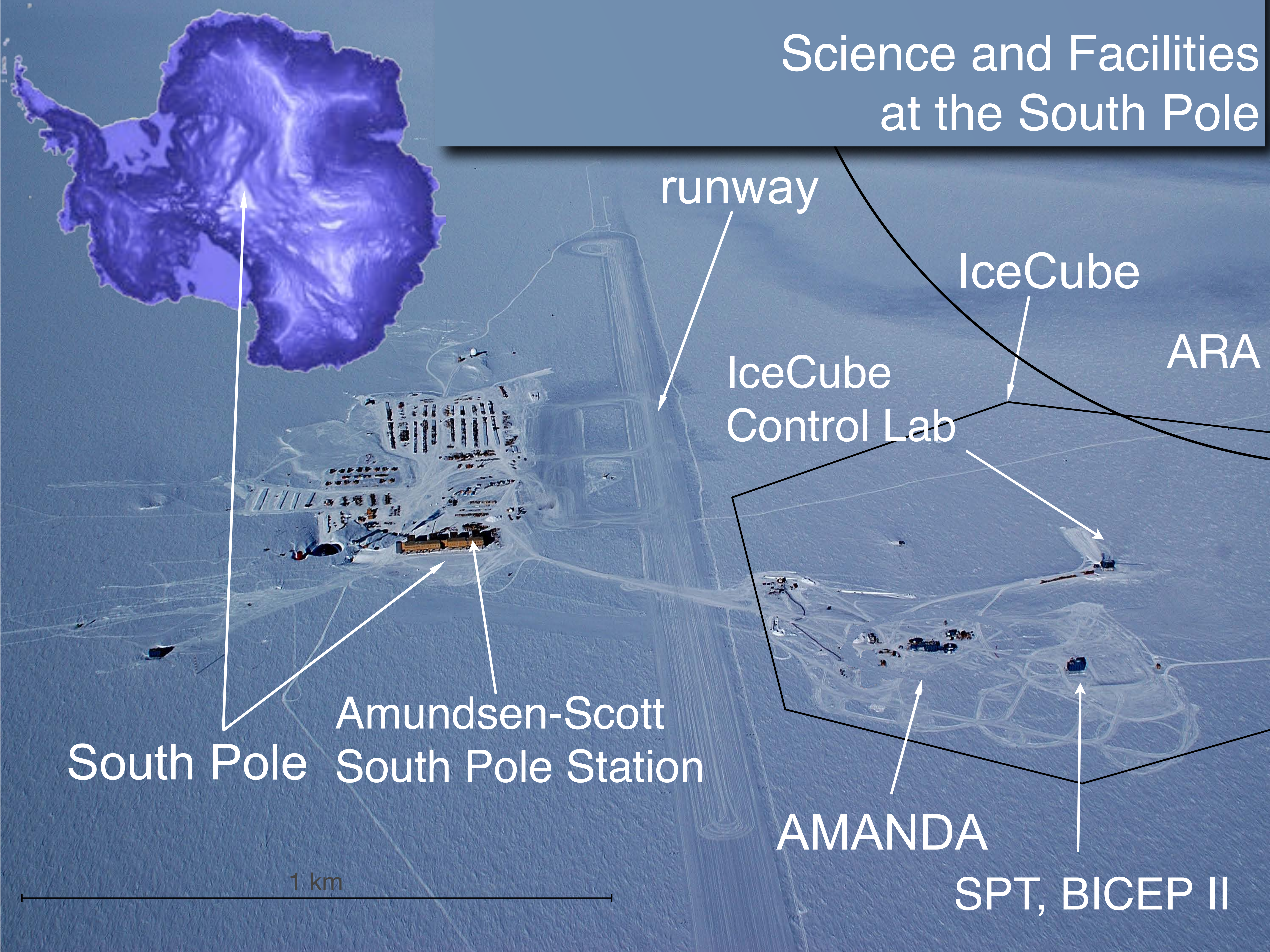
- A 17 kg NaI detector
- Operation since Feb. 2011
- Data run from June 2011

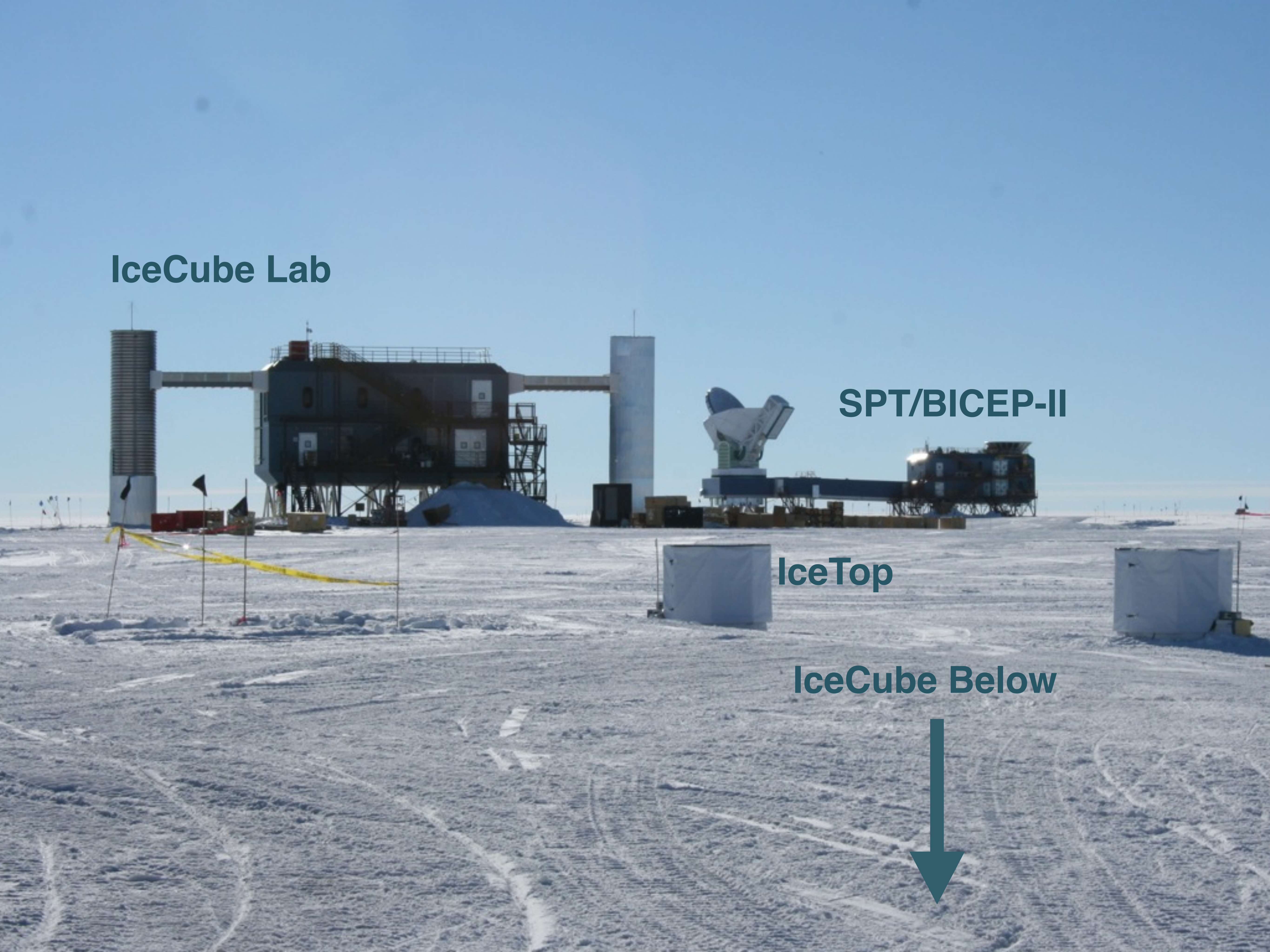
Demonstrated:

- Feasibility of deploying a remotely-operable dark matter detector in the Antarctic Ice
- Stability of the environment
- Radiopurity of the antarctic ice / hole ice
- Explore the capability of IceCube to veto muons



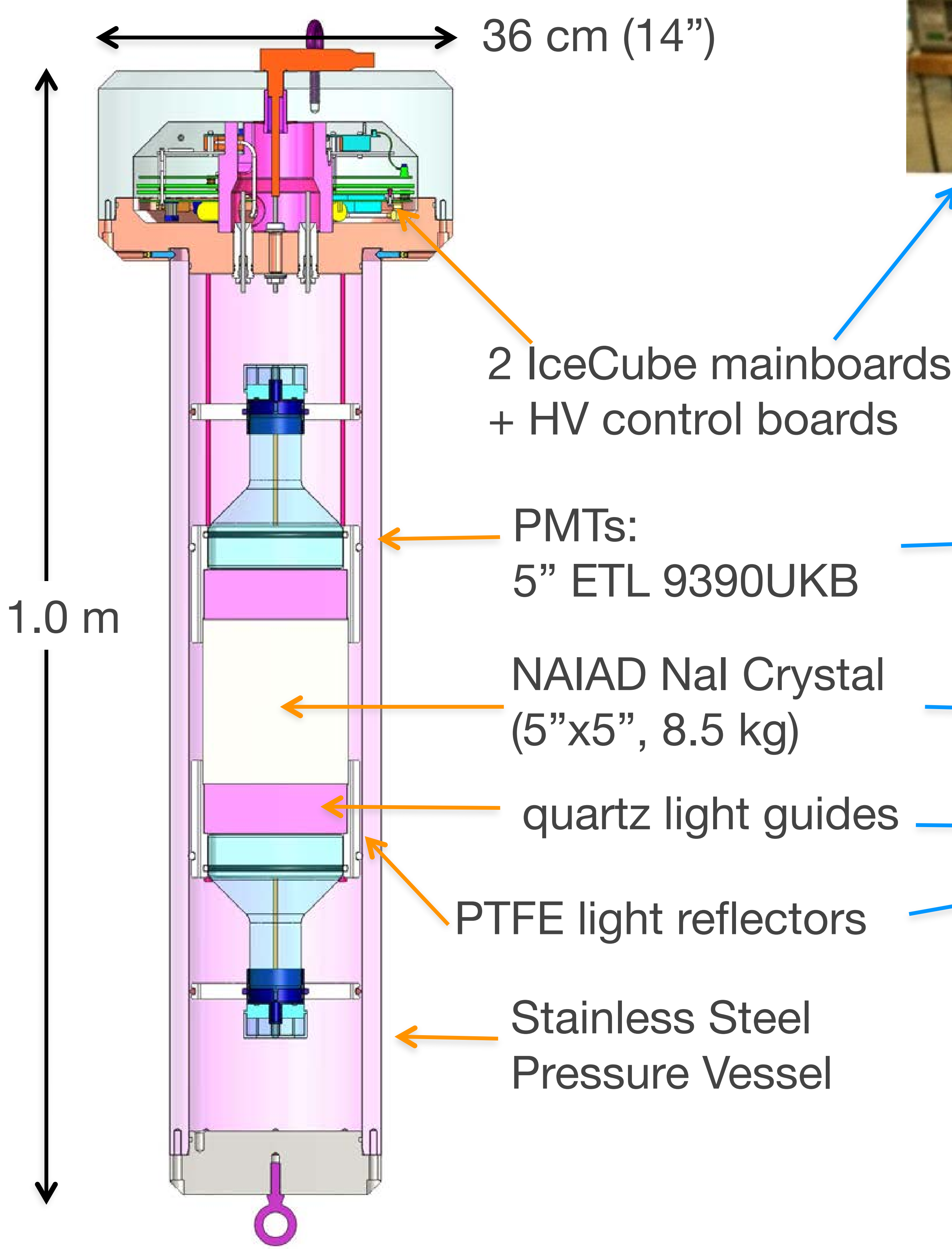
# Science and Facilities at the South Pole

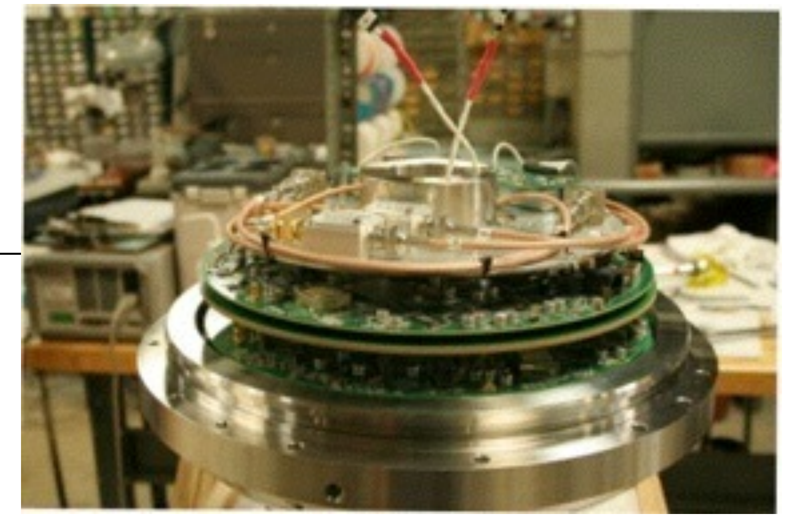


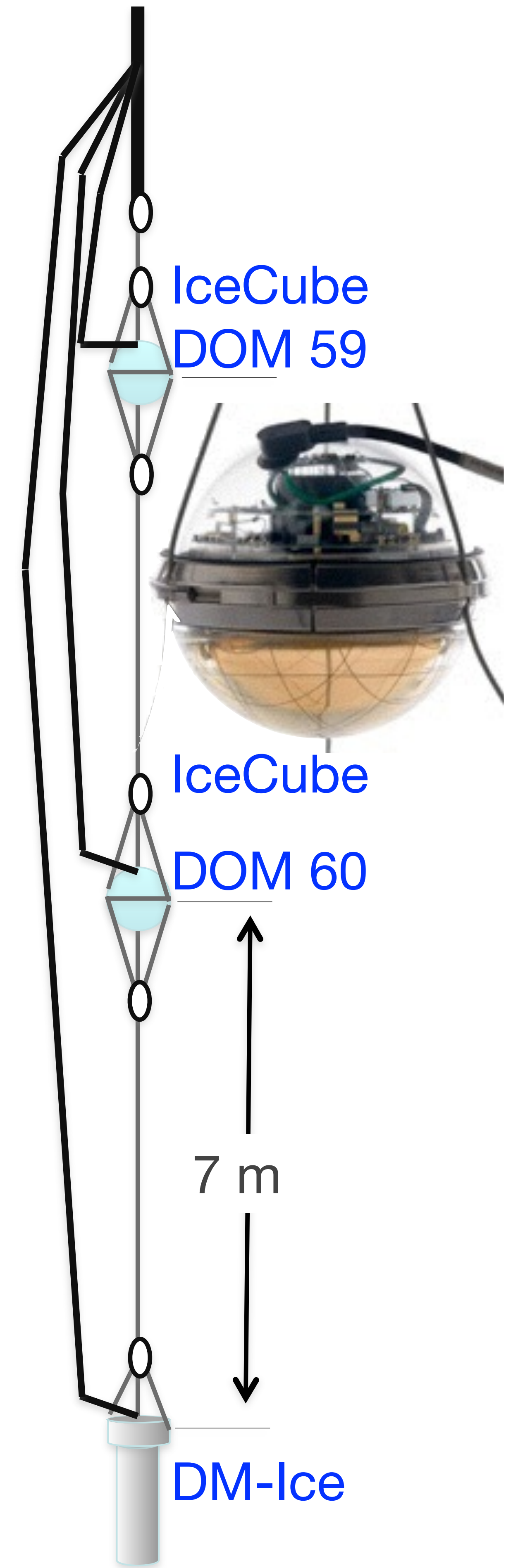

IceCube Lab
SPT/BICEP-II
IceTop
IceCube Below


IceCube Detector Completion
December, 2010

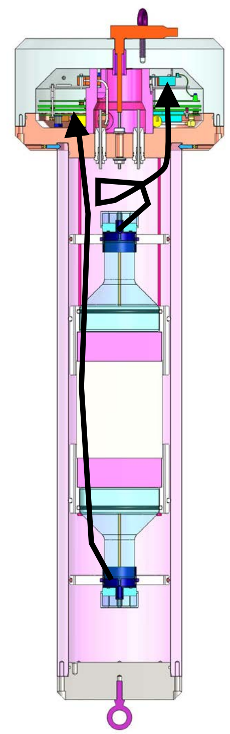
# DM-Ice-17 Detector

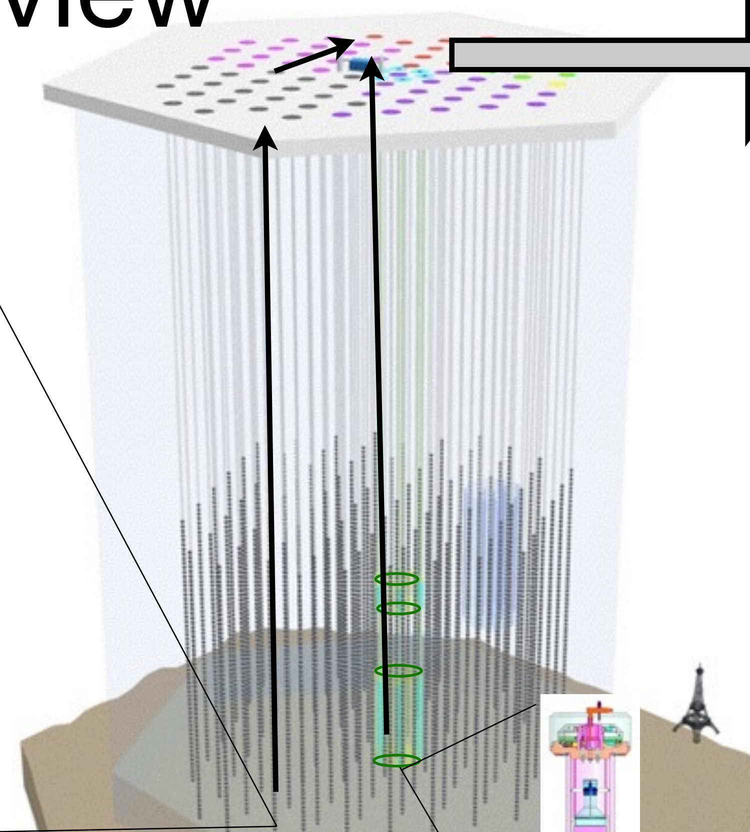


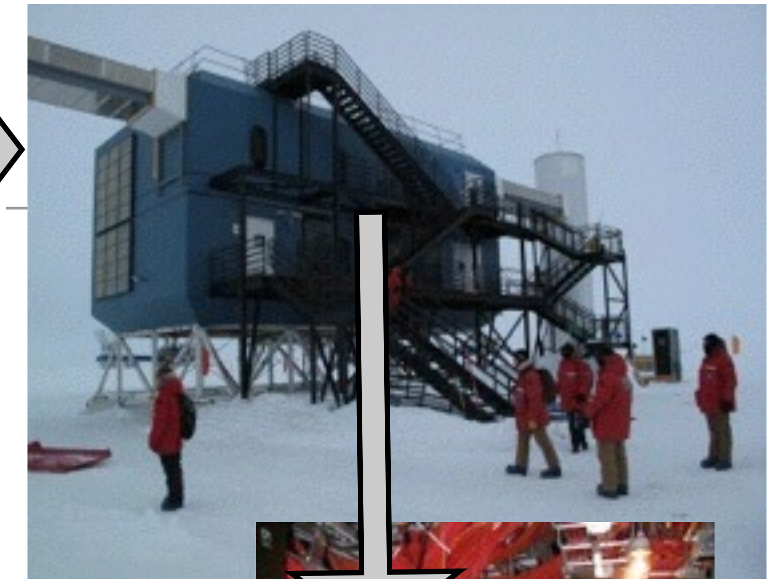



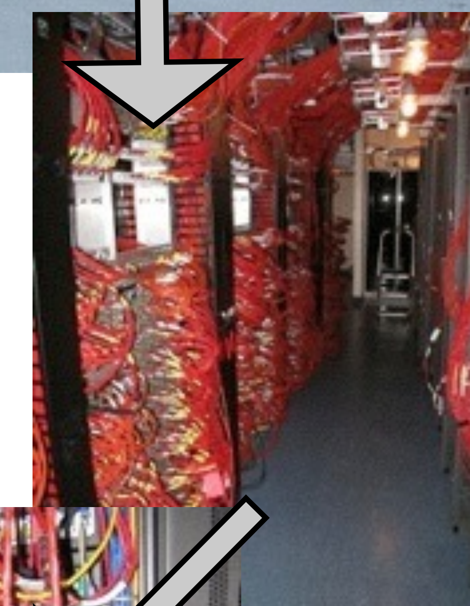


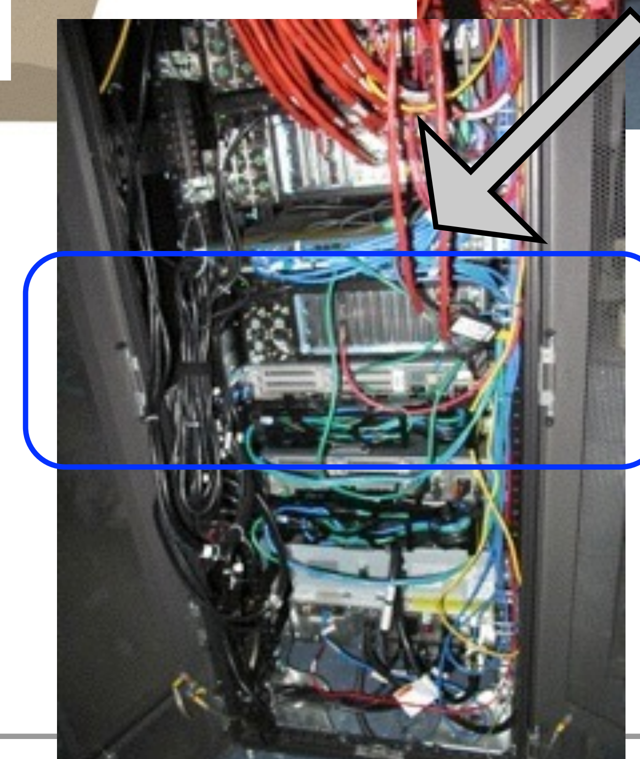
# DM-Ice17 DAQ Overview









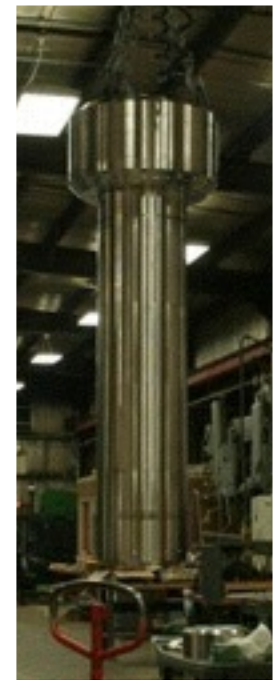


- Remotely programable sample rate, HV & threshold
- Each PMT set to trigger ~0.2 spe
- Waveform recorded only when coincidence between both PMTs w/in 800 ns on a single crystal
- Waveform from each PMT digitized separately in the ice by IceCube mainboards and sent to hub
- Time stamp synchronized to IceCube GPS and calibrated for transit time
- Data sent over satellite to Madison, WI

# DM-Ice-17 Construction & Deployment

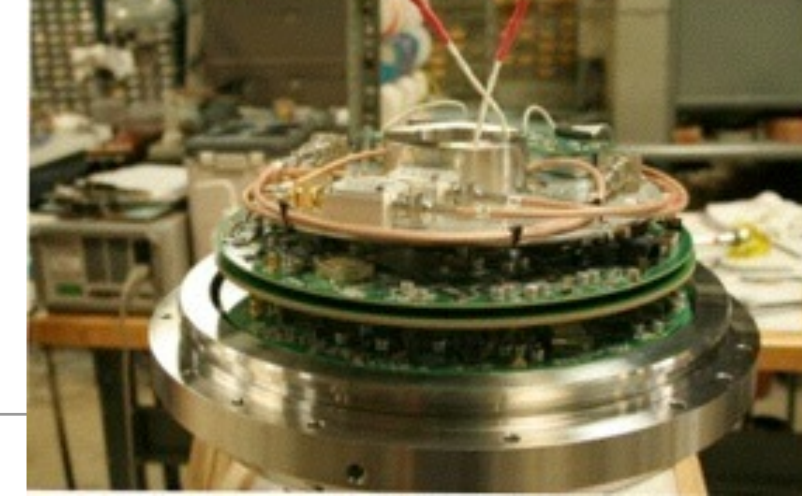
Design begin Feb. 2010



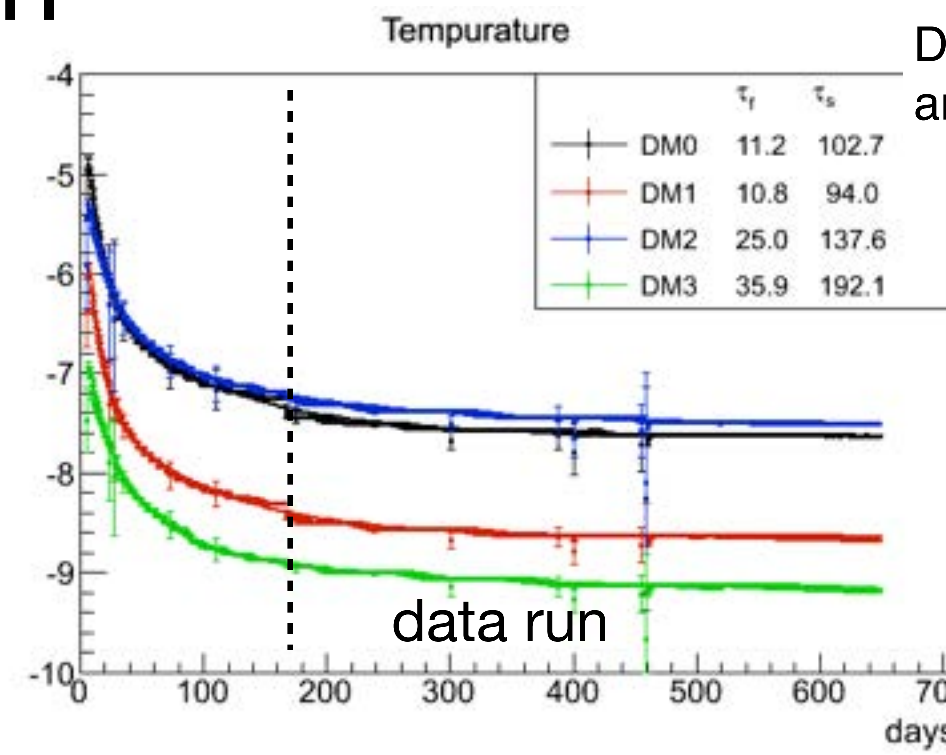




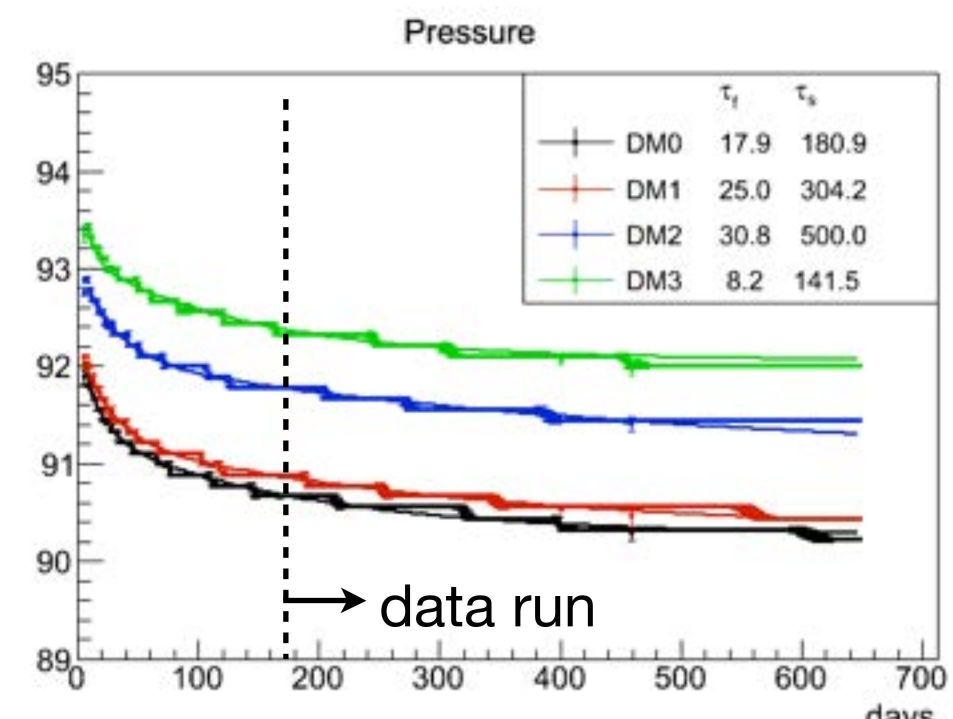
# DM-Ice17: Detector Operations

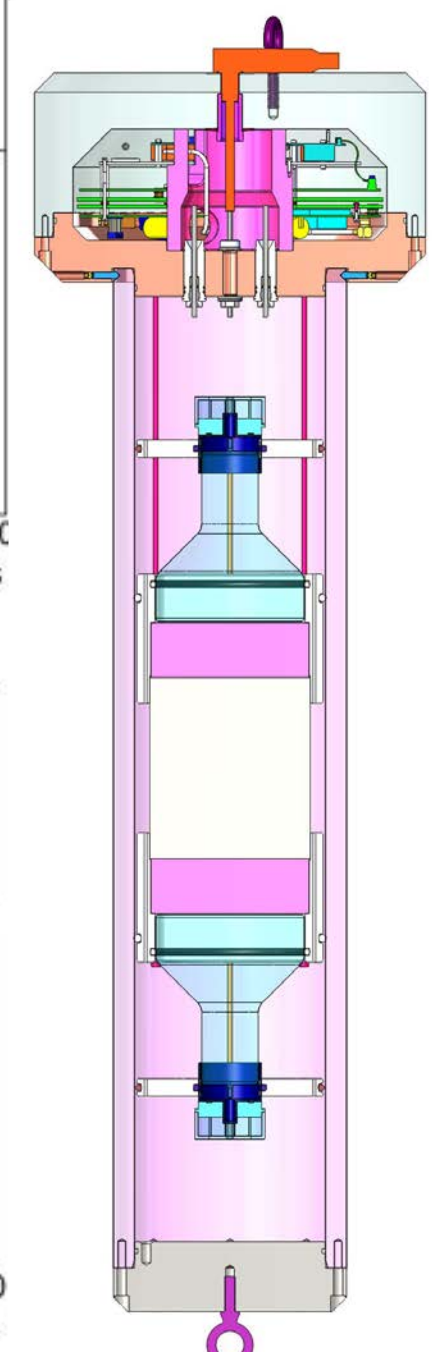


- **Physics data taking since June 2011**
- Monitored quantities:
  - Temperature of the boards
    - ~10°C above surrounding ice
    - Fast (2-3 weeks) decrease during freeze-in
    - slower decrease over a few months after freeze-in
  - Pressure follows similar trend as temperature (ADC resolution limited)
- Values recorded every 2 sec. before April 2012. Every 60 sec. since April 2012.



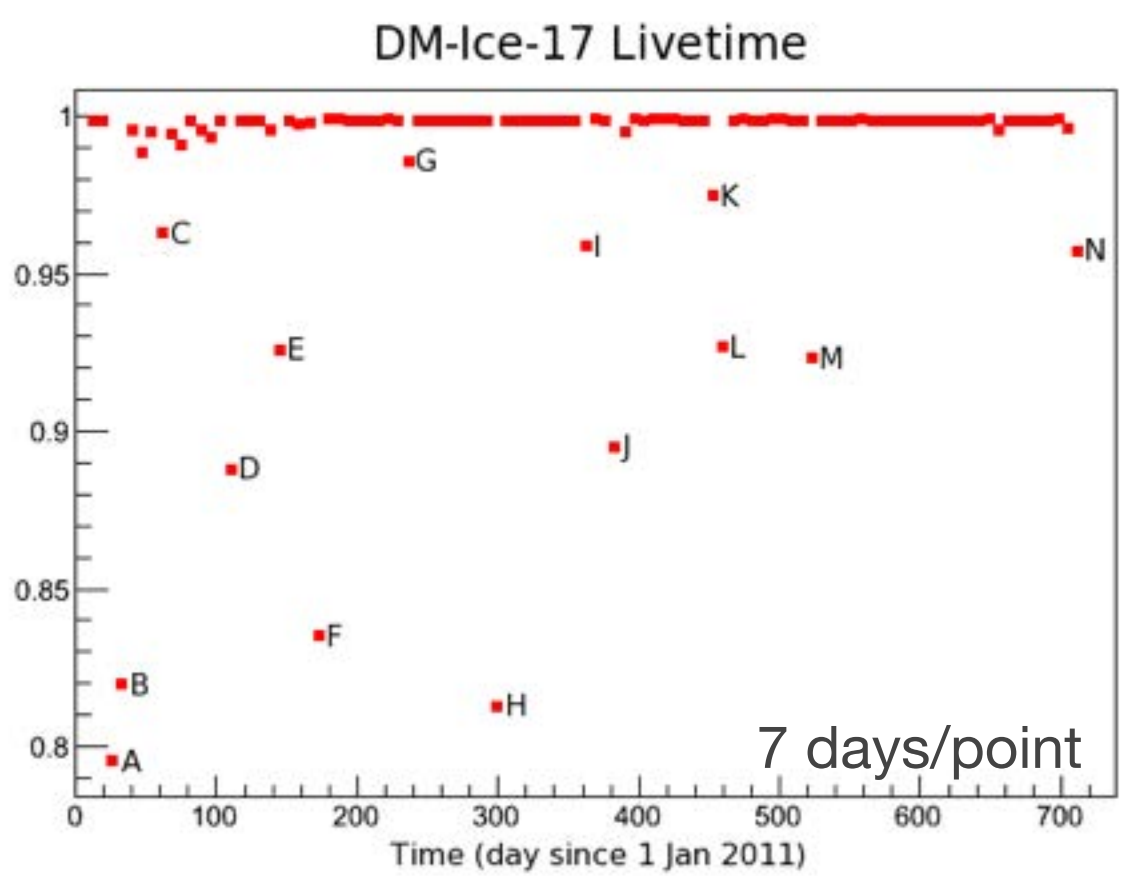

DM-Ice Collaboration
arXiv:1401.4804v1



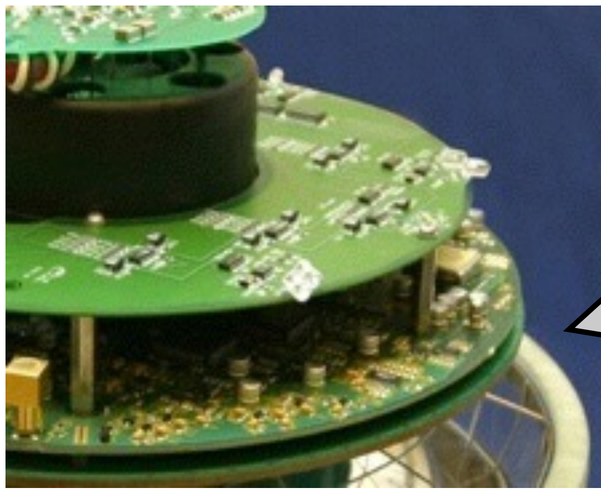
# Detector Uptime

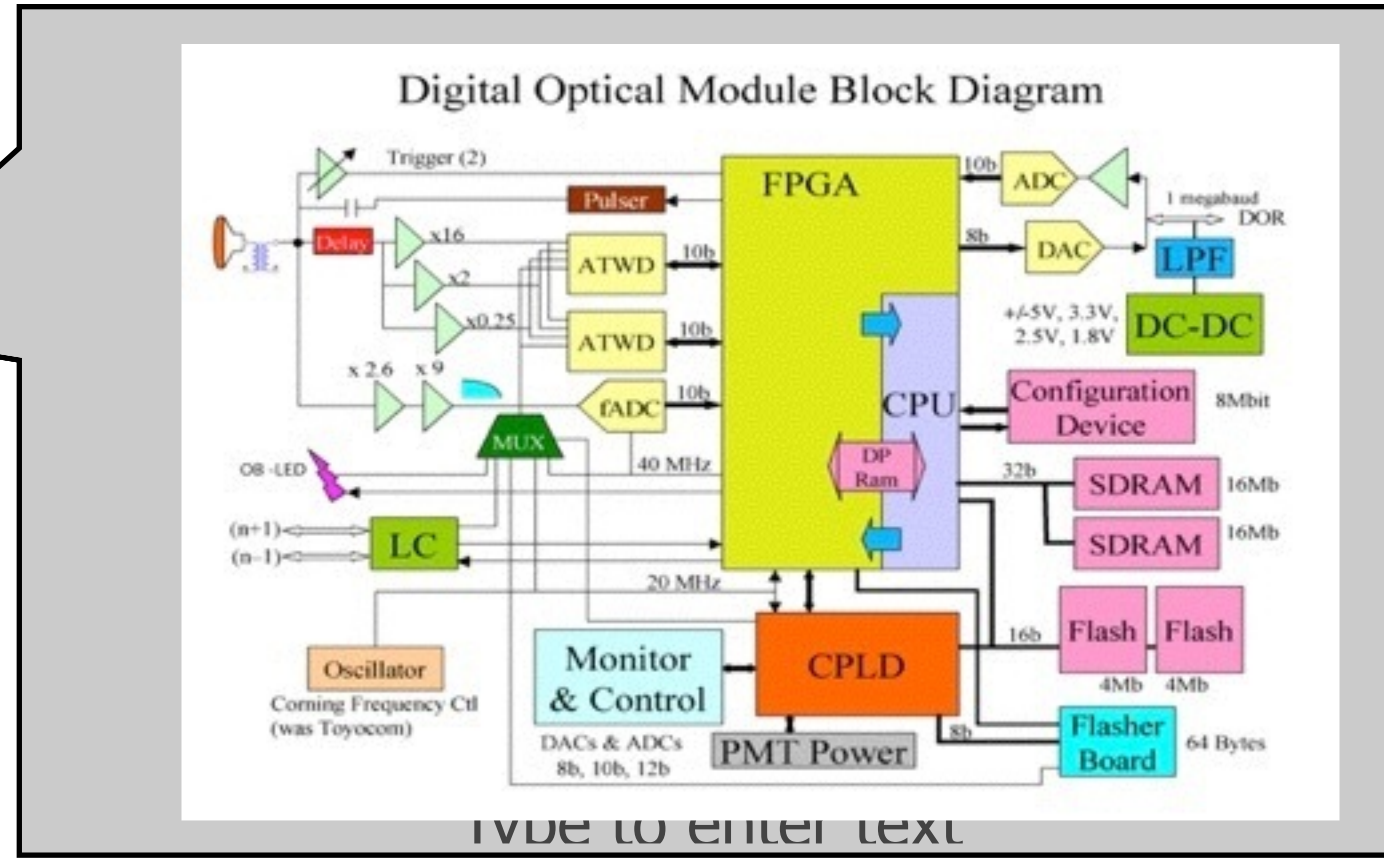
- Commissioning and optimization from Feb - June 2011
- Data run since June 2011
- 99.8% uptime for most weeks with well defined down time for occasional power cycling + pedestal and dark noise runs

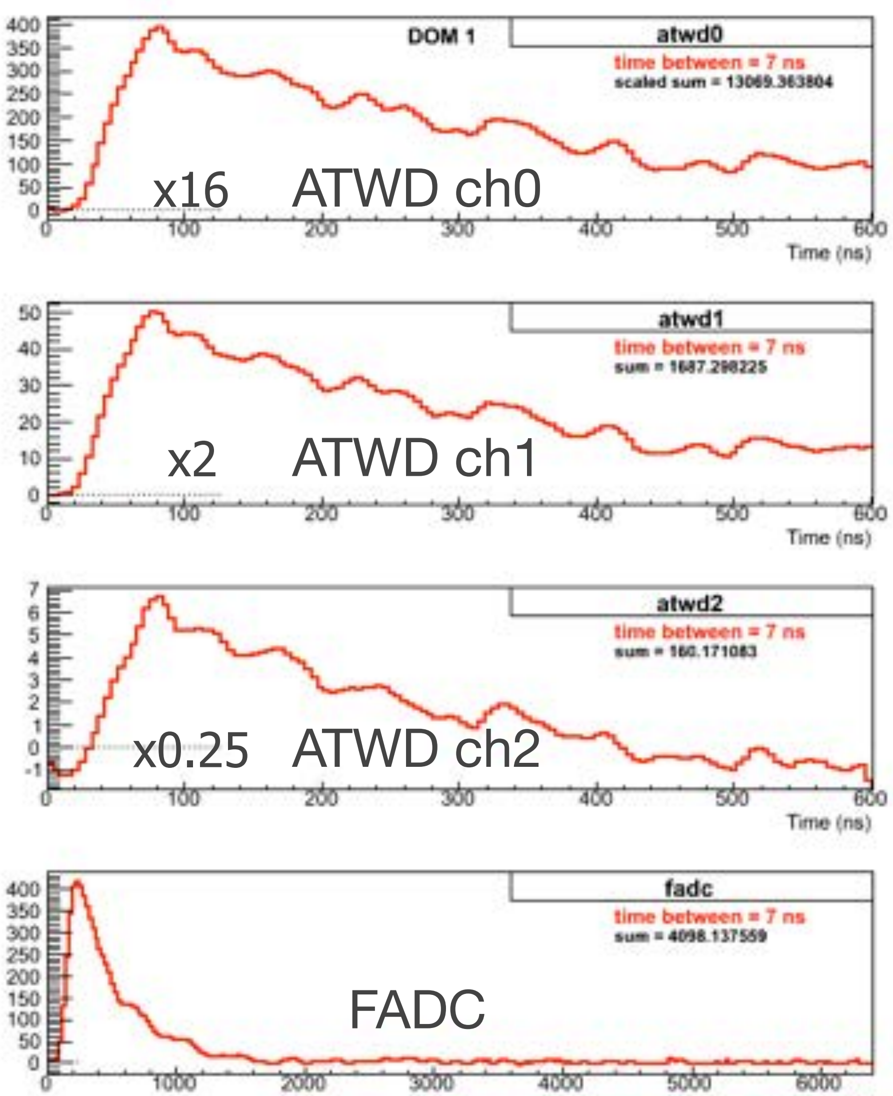



DM-Ice Collaboration
arXiv:1401.4804v1

# Capturing Waveforms with IceCube Mainboards

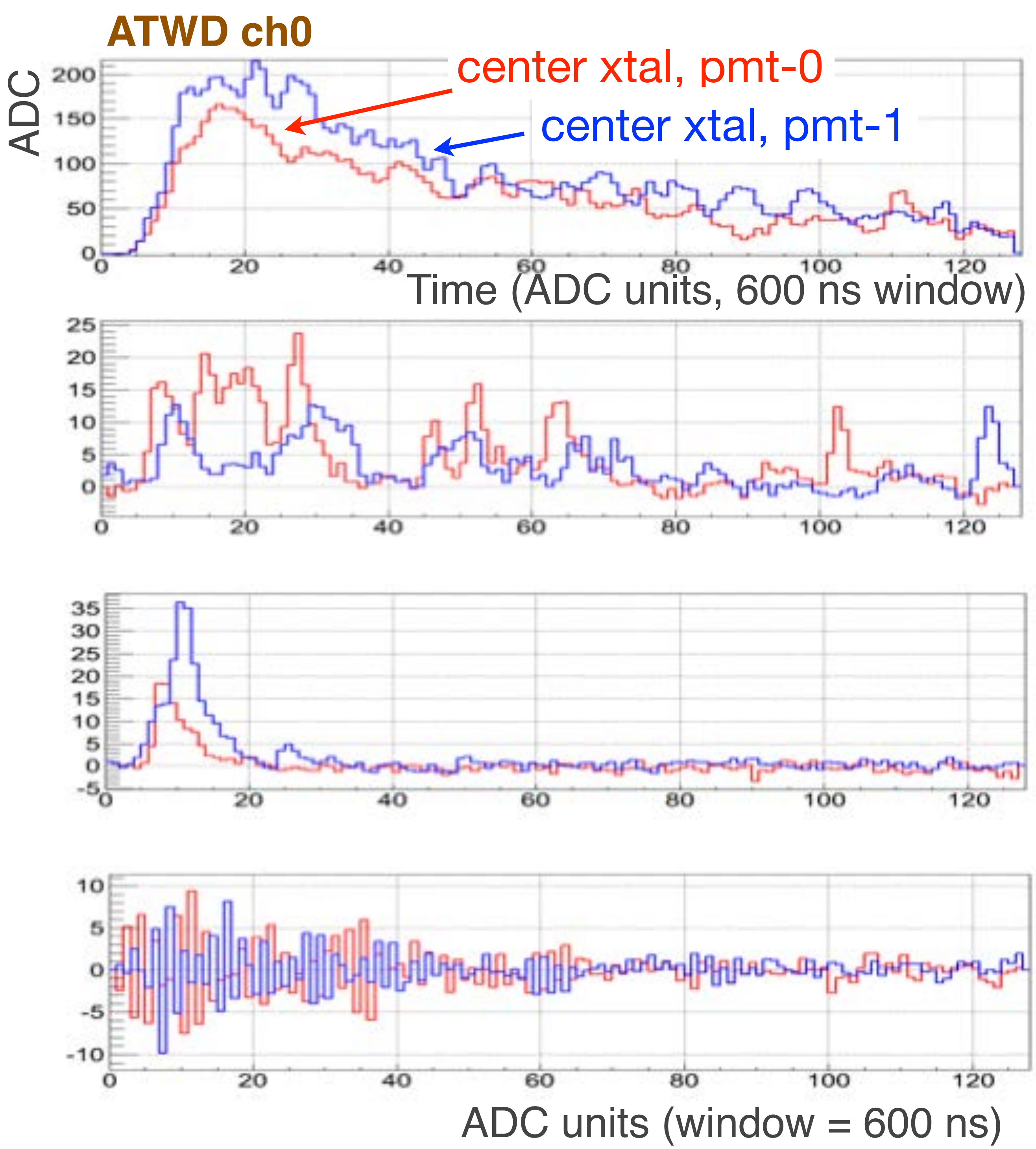





- 40 MHz 10-bit flash ADC for slow high energy events
- 2 parallel Analog Transient Waveform Digitizer (ATWD) chips with 10-bit resolution and sampling speeds programmable from 250 MHz to 1 GHz
- Each ATWD contains 3 gain paths: x16, x2, x0.25 looking at the PMT input and giving an effective 14-bits of resolution to span the PMT dynamic range
- Reprogrammable from surface

# Waveform Examples




**high energy events** (>100  keV)

Typical scintillation pulses with decay time ~350 ns

**low energy events** (<100 keV)

single photo-electrons visible

**“thin” pulses**

Fast pulses with large amplitudes

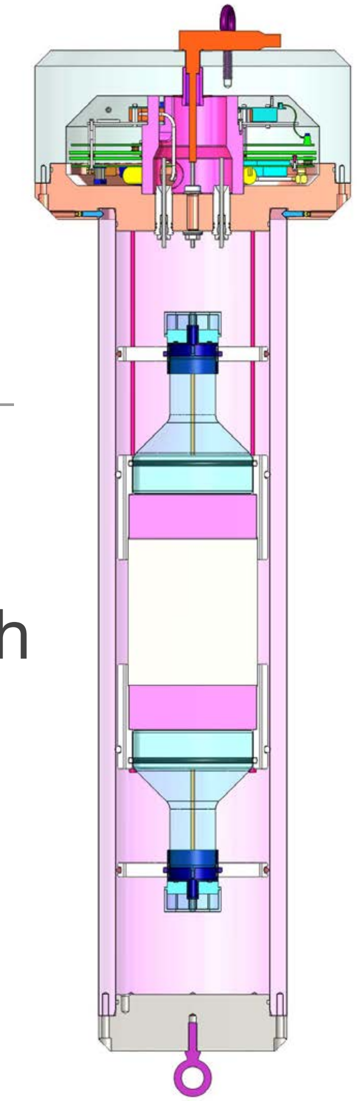
cut via waveform

**“EMI” events**

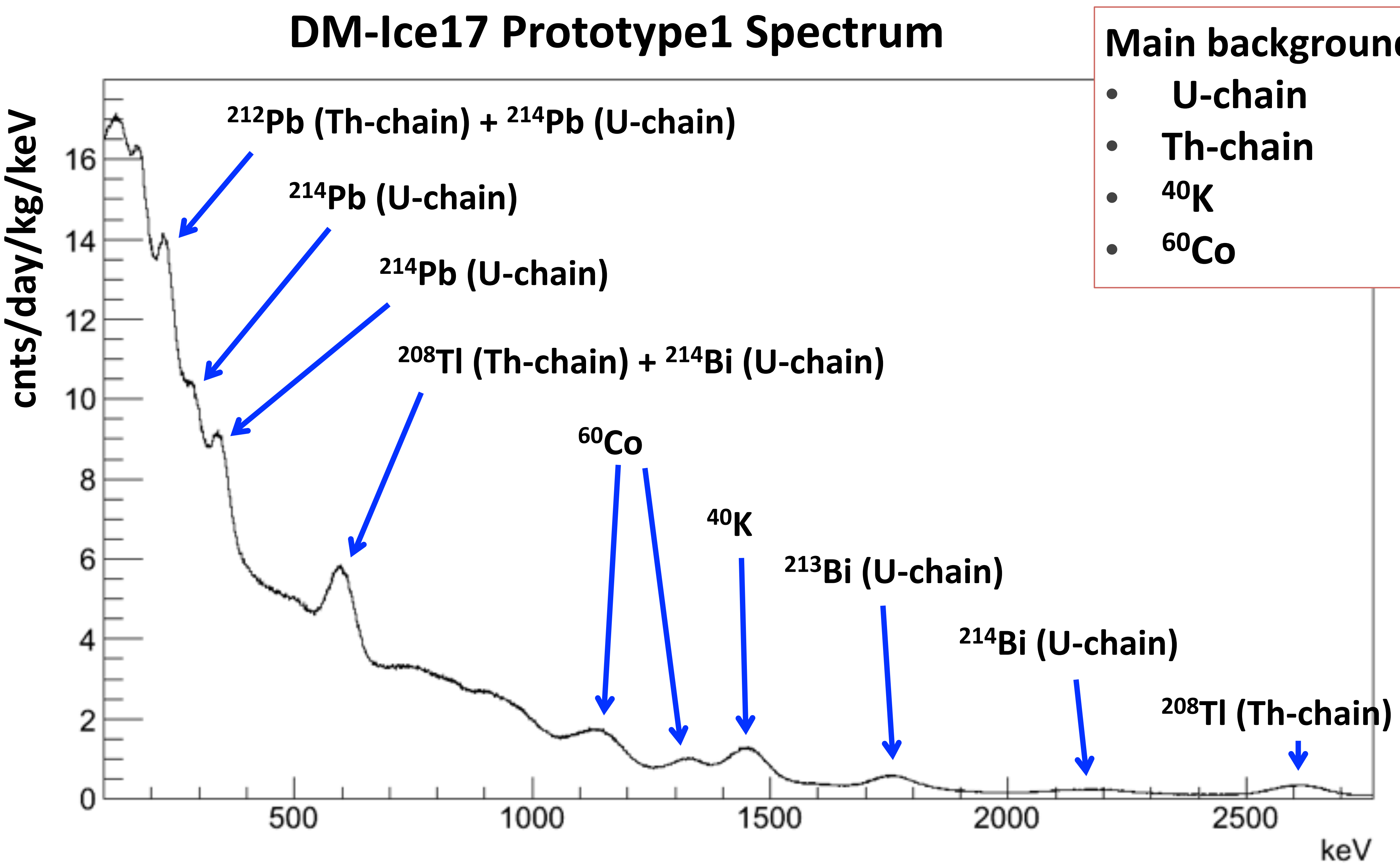
Interference with detector monitoring.

Well characterized by timing and shape.

(no interference with IceCube or ARA seen)

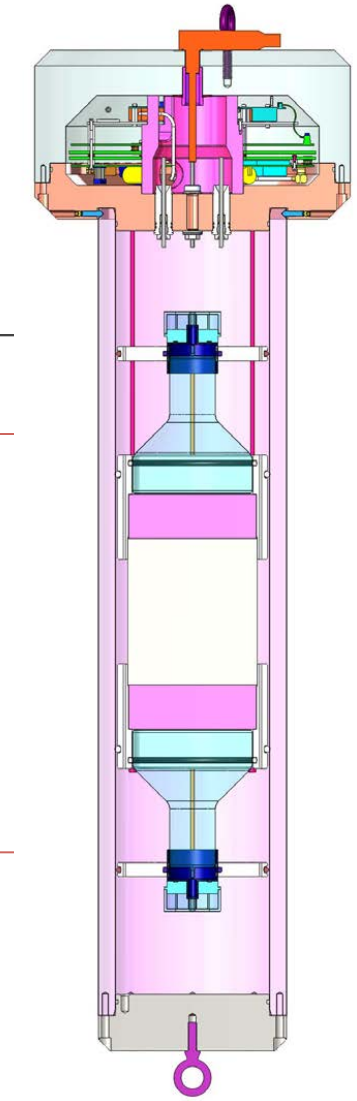


# DM-Ice17 Spectrum




**Main backgrounds:**

- U-chain
- Th-chain
- $^{40}K$
- $^{60}Co$

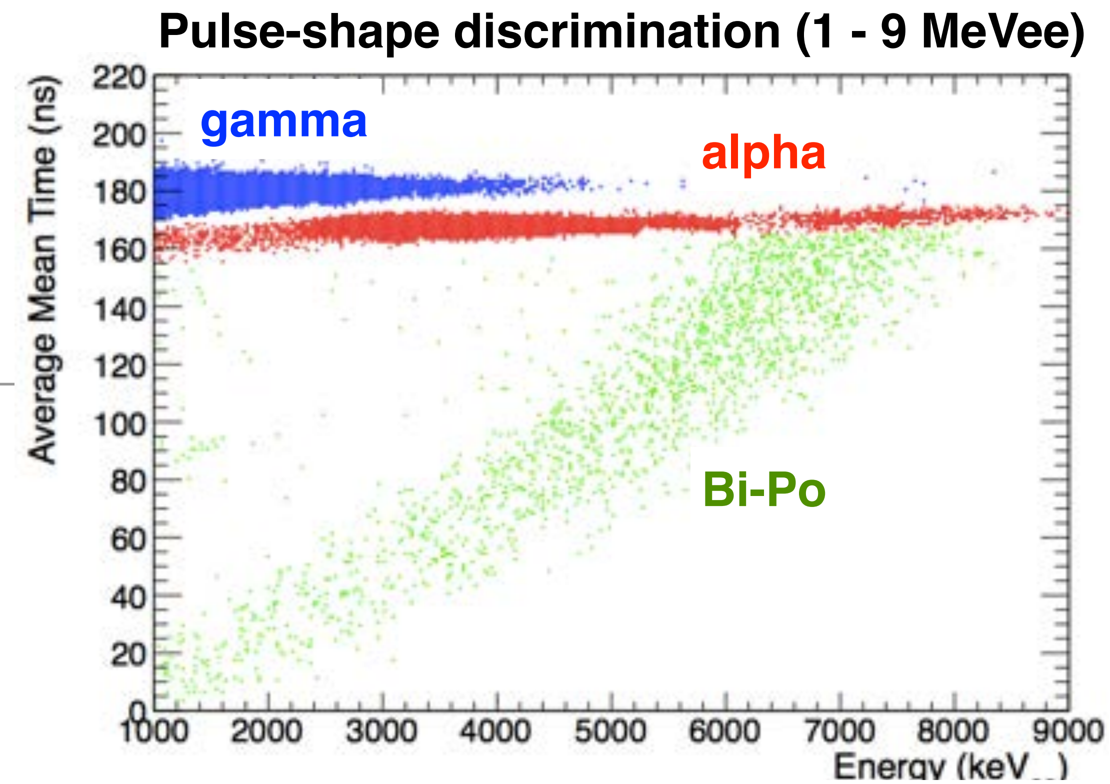


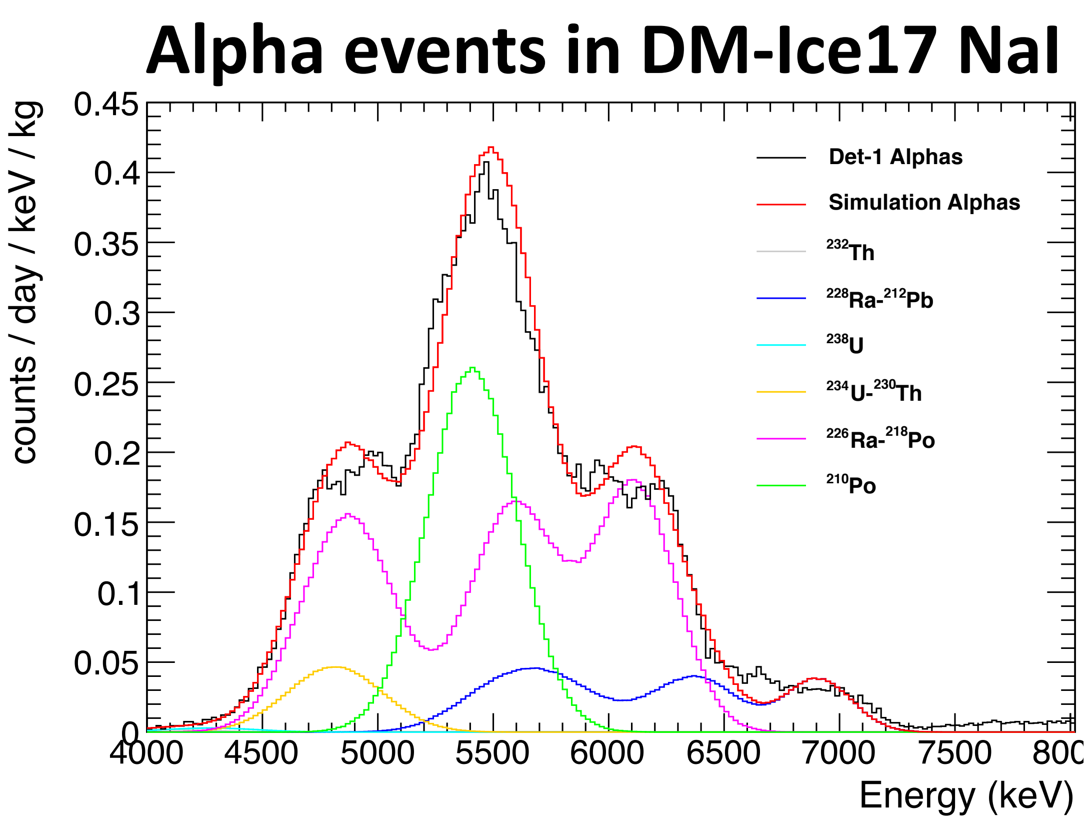
**Internal contamination lines used for calibration**

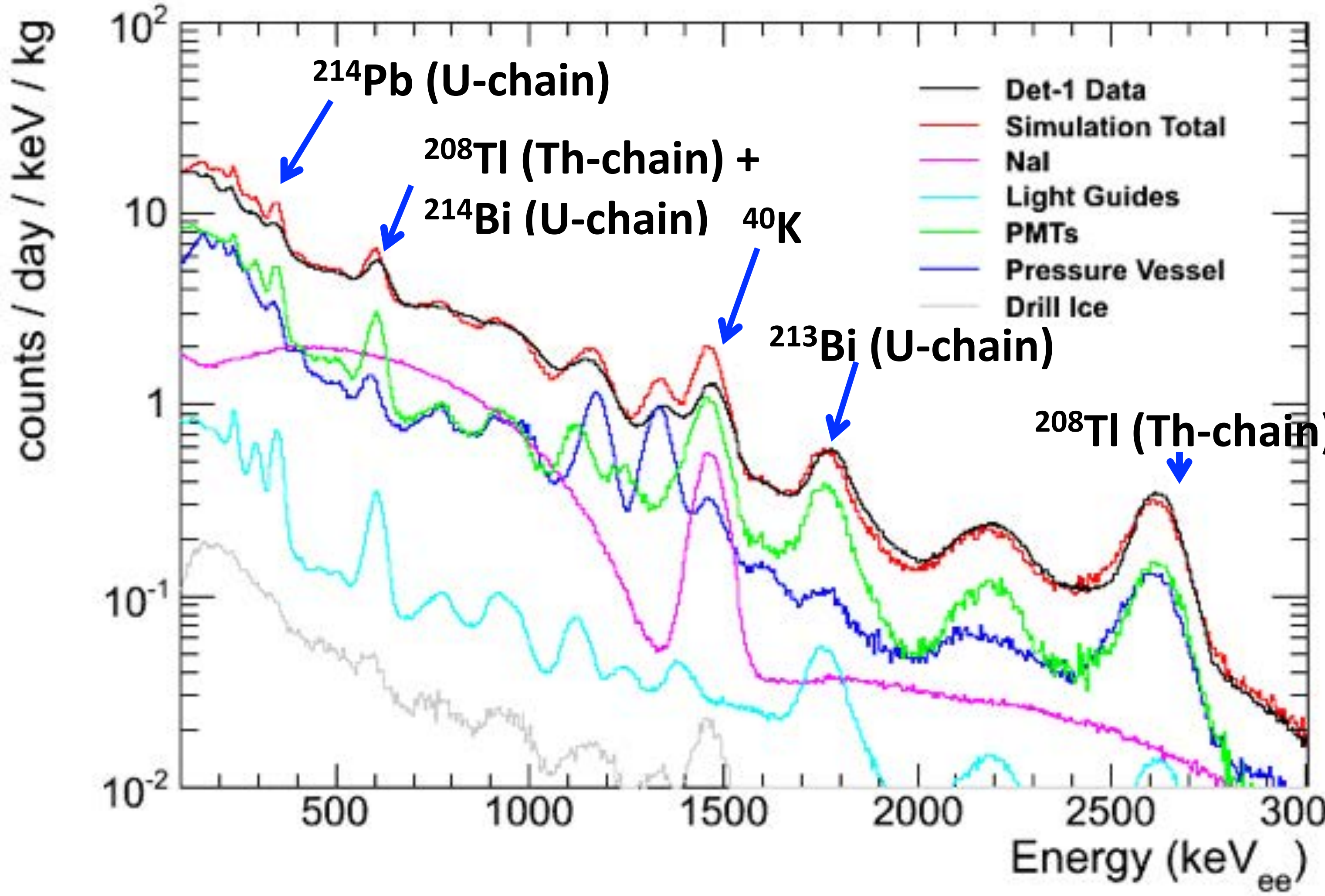
DM-Ice Collaboration
arXiv:1401.4804v1

# Spectrum vs. Simulation

- Good agreement with simulation
- Simulation based on:
  - NaI from alphas and K from data
  - radioassay of spare parts



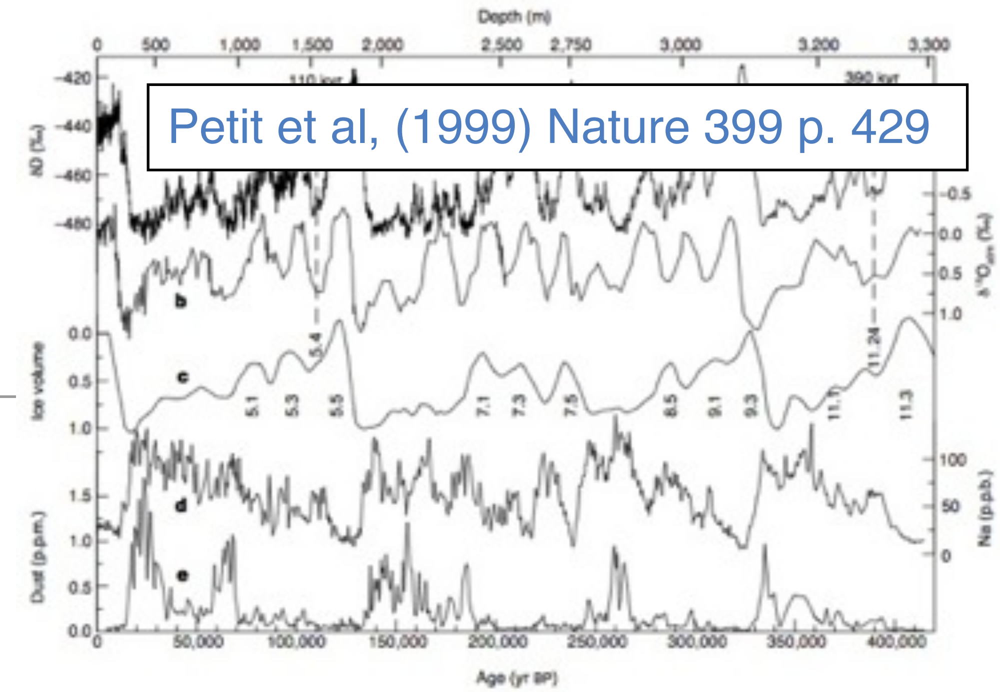





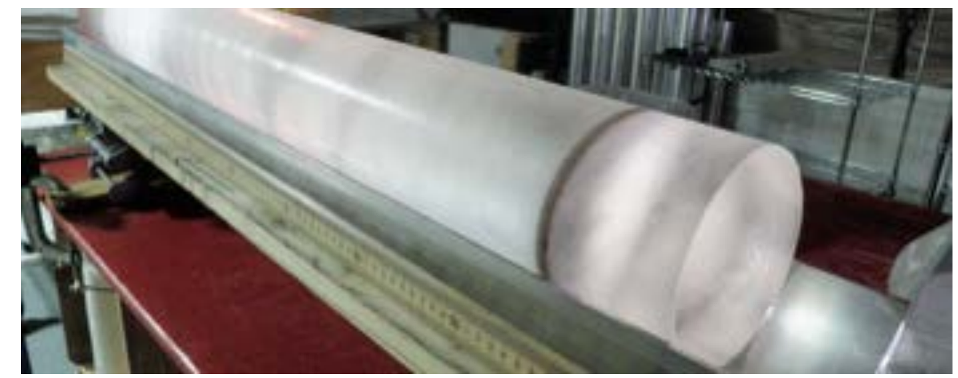

DM-Ice Collaboration
arXiv:1401.4804v1

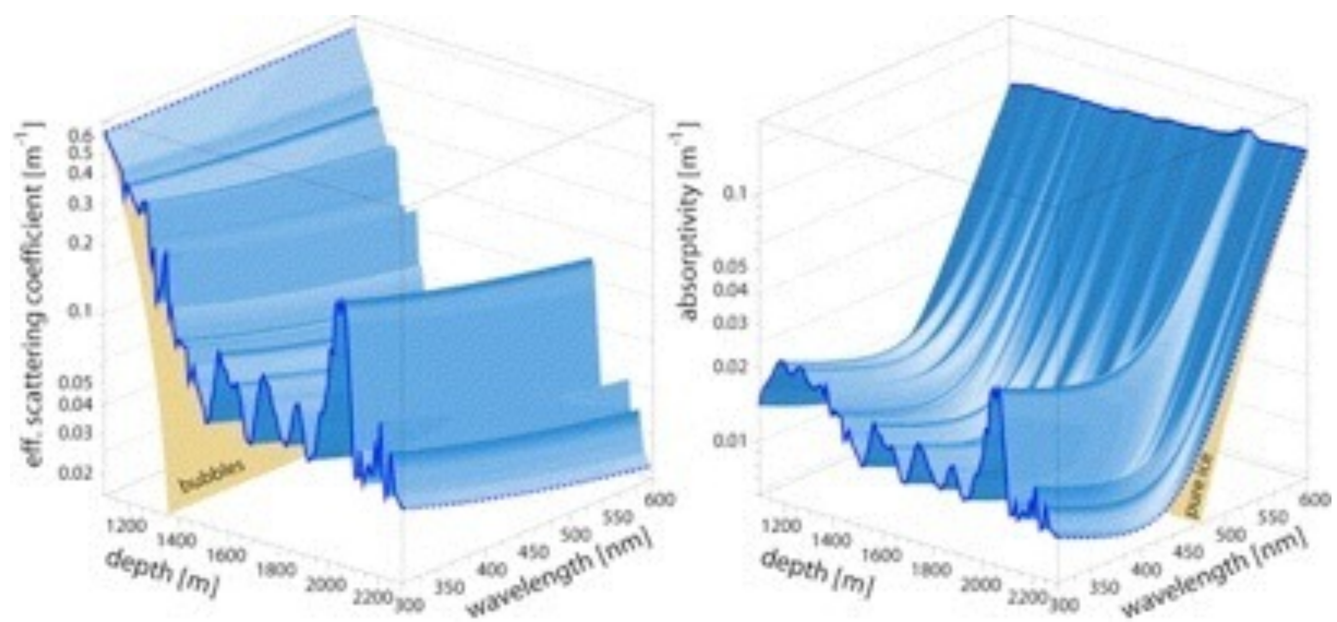
# Antarctic Ice: Radiopurity

- Measurements from ice cores at Vostok.
- Absorption and scattering lengths measured by AMANDA/ IceCube
- -2500 m at South Pole is ~100,000 years old
- Most of the impurities come from volcanic ash, < 0.1 ppm
- Radioactive contaminants in ice:
  - U ~ 0.1 - 1 ppt
  - Th ~ 0.1 - 1 ppt
  - K ~ 0.1 - 1 ppb




Petit et al, (1999) Nature 399 p. 429



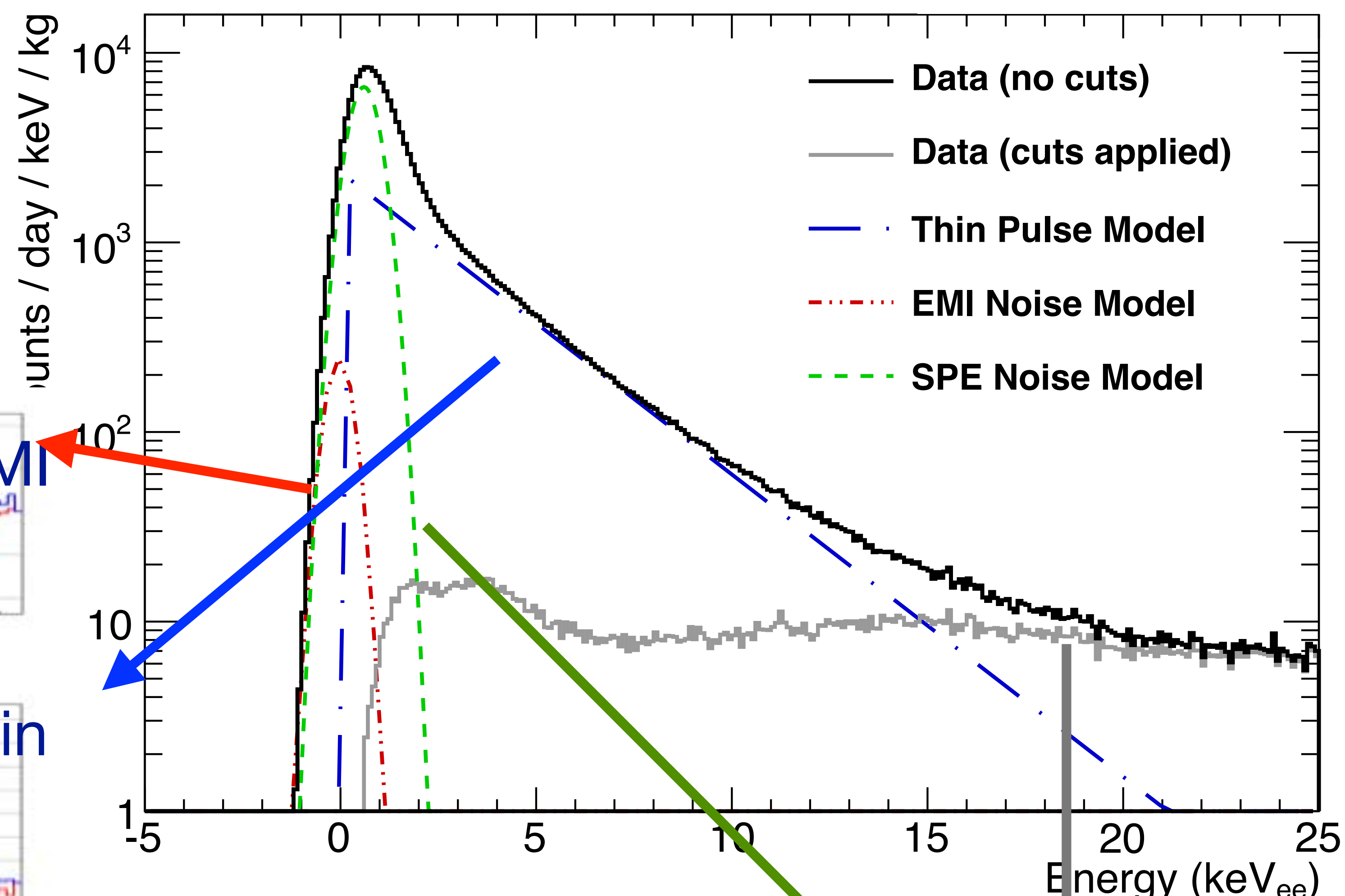


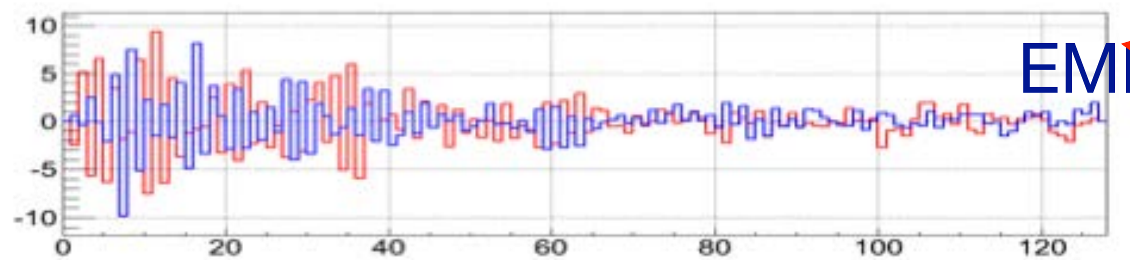

J. Geophys. Res., 111, D13203 (2006)

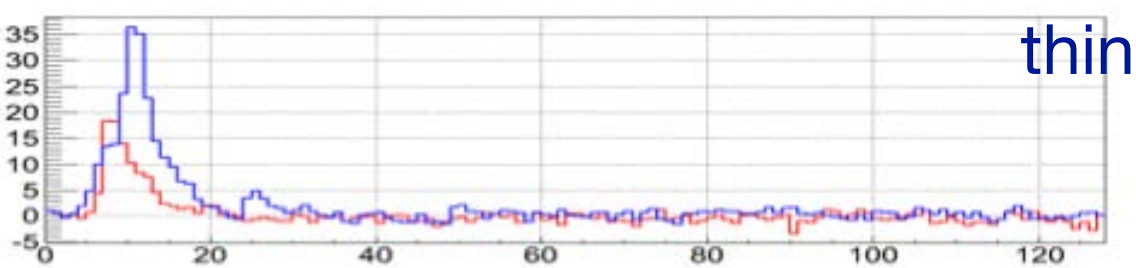
# Low Energy Spectrum

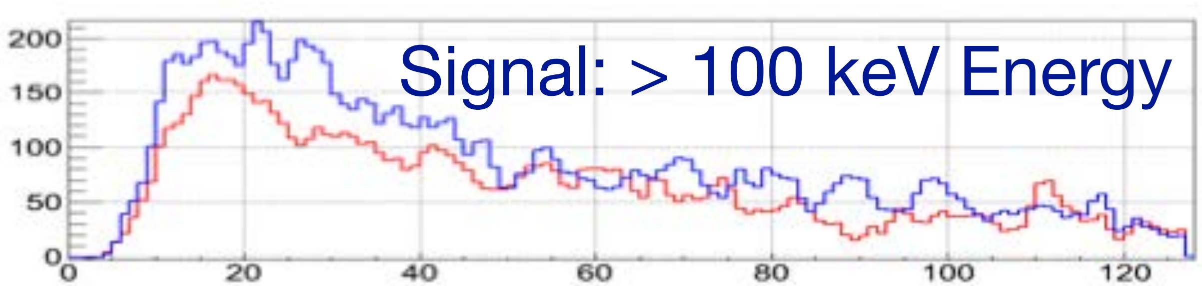
- Spectrum below 10 keV dominated by “thin” pulses.
- Below 2 keV: combination of single-photoelectrons & electronics noise

DM-Ice Collaboration
arXiv:1401.4804v1

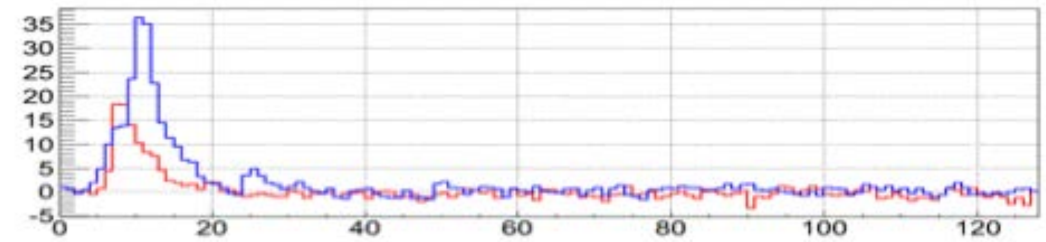


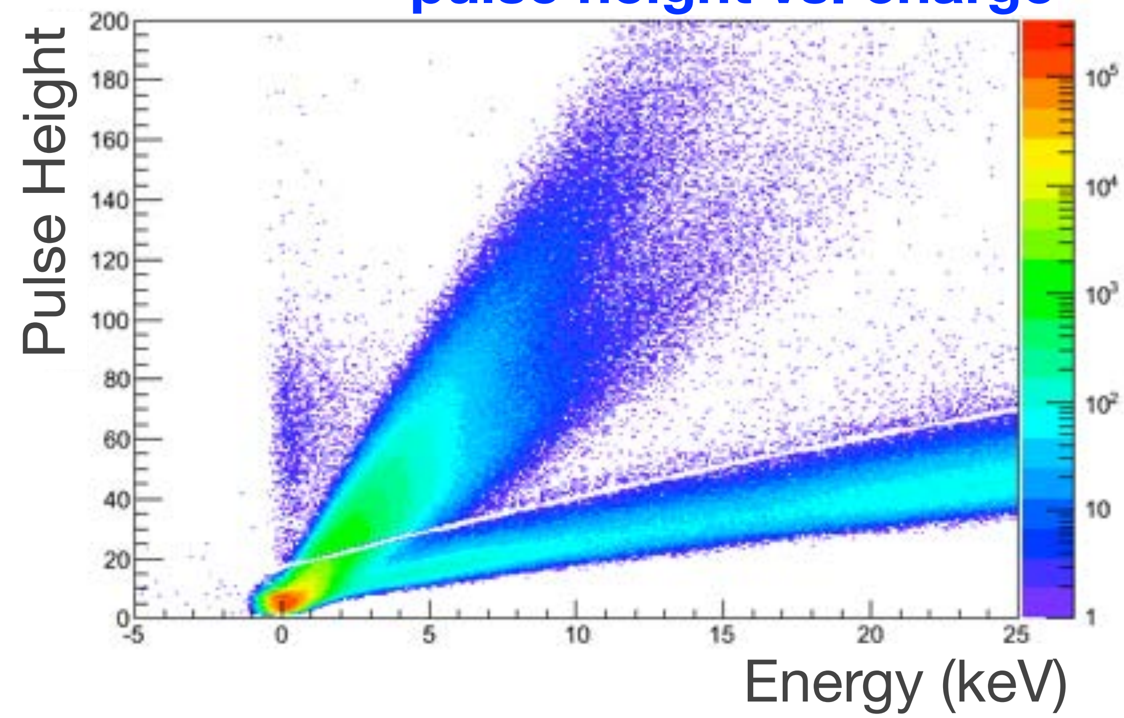




# Event Selection: “Thin” pulses

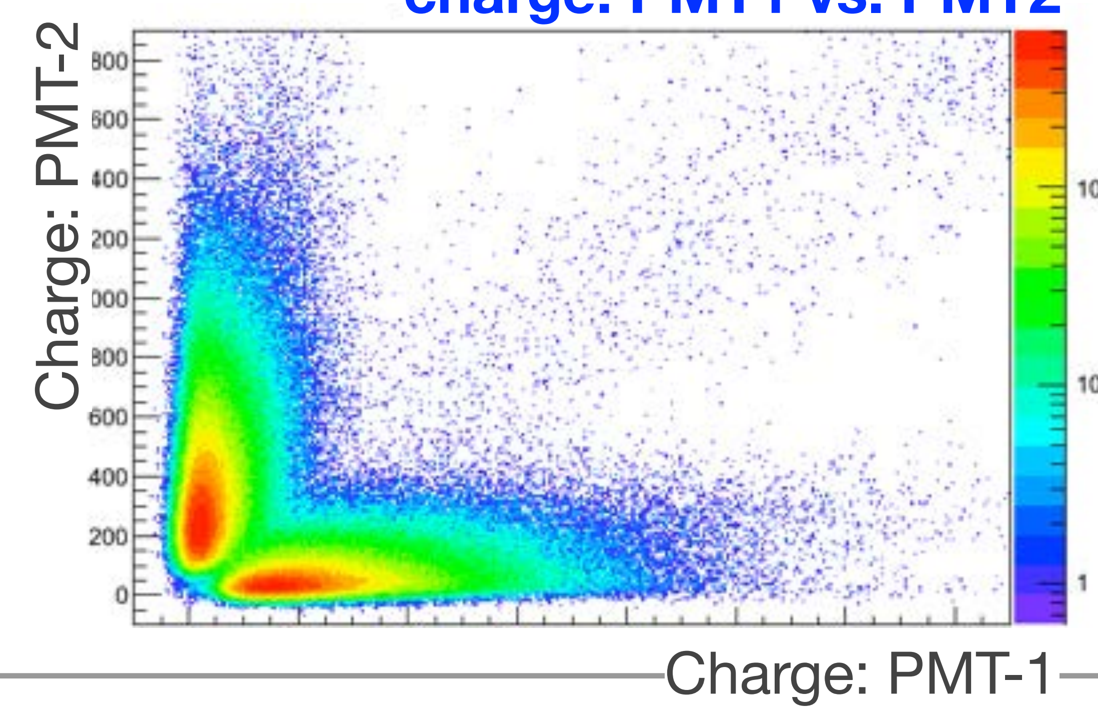



- Characteristics:
  - high pulse-height relative to  charge
  - asymmetric between two PMTs
- 90% of events between 5-10 keV are “thin”
- Current cut effective above 7 keV

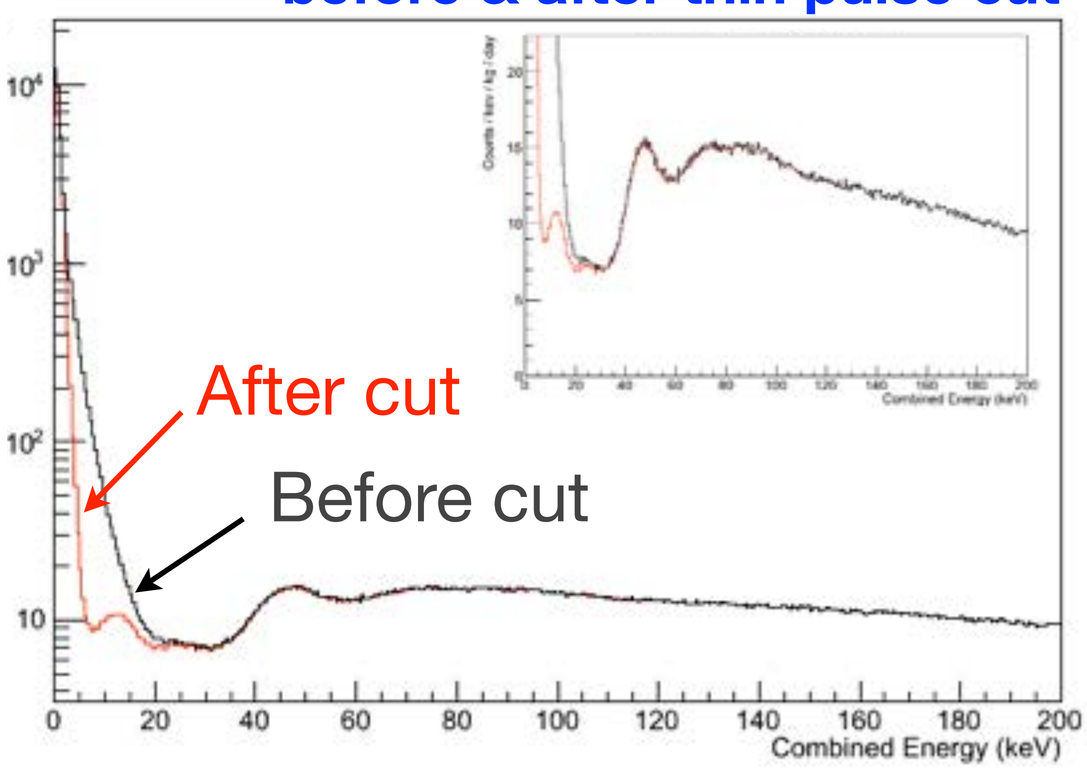
**pulse height vs. charge**




**charge: PMT1 vs. PMT2**

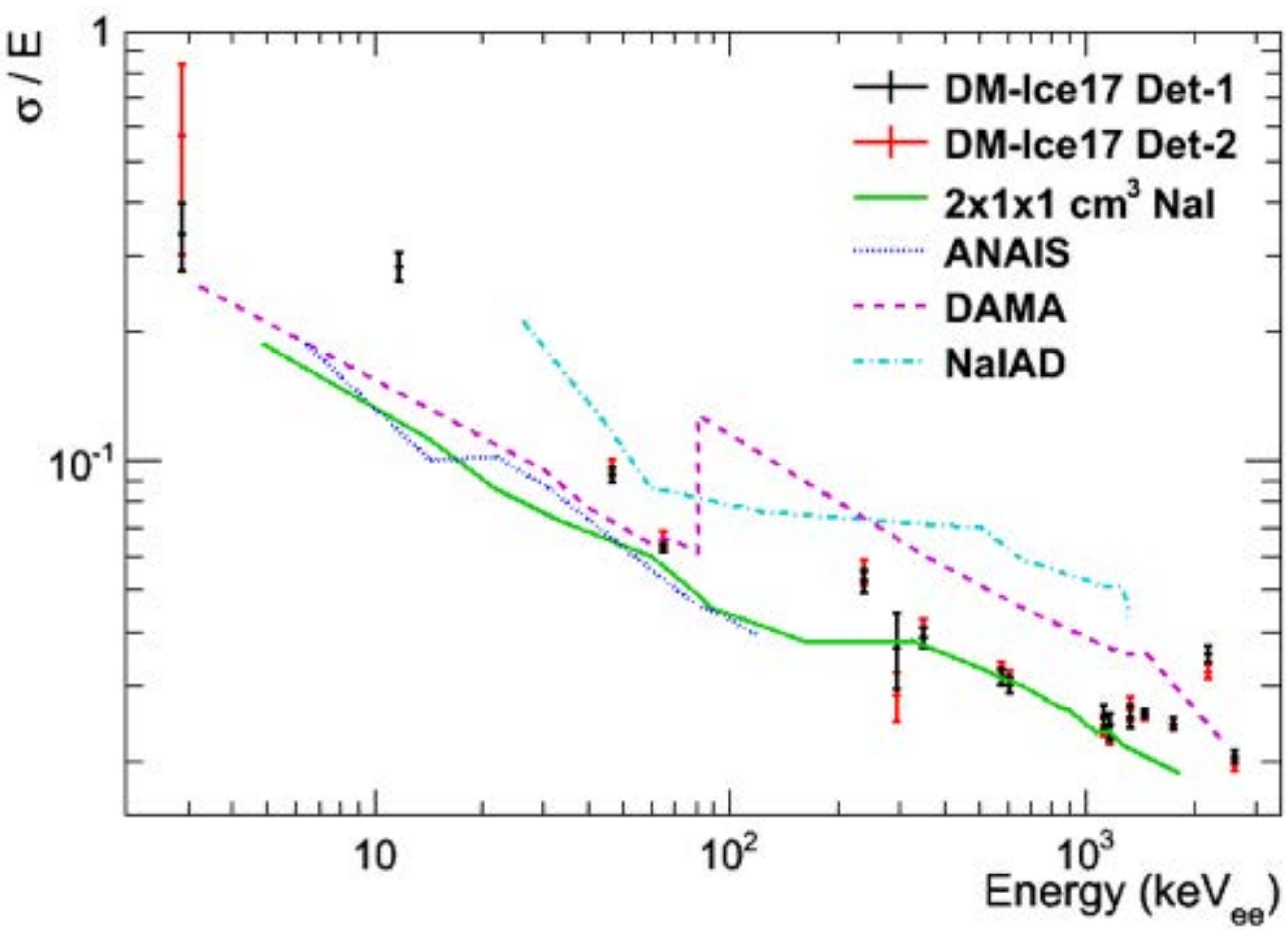



**energy spectrum:**
**before & after thin pulse cut**

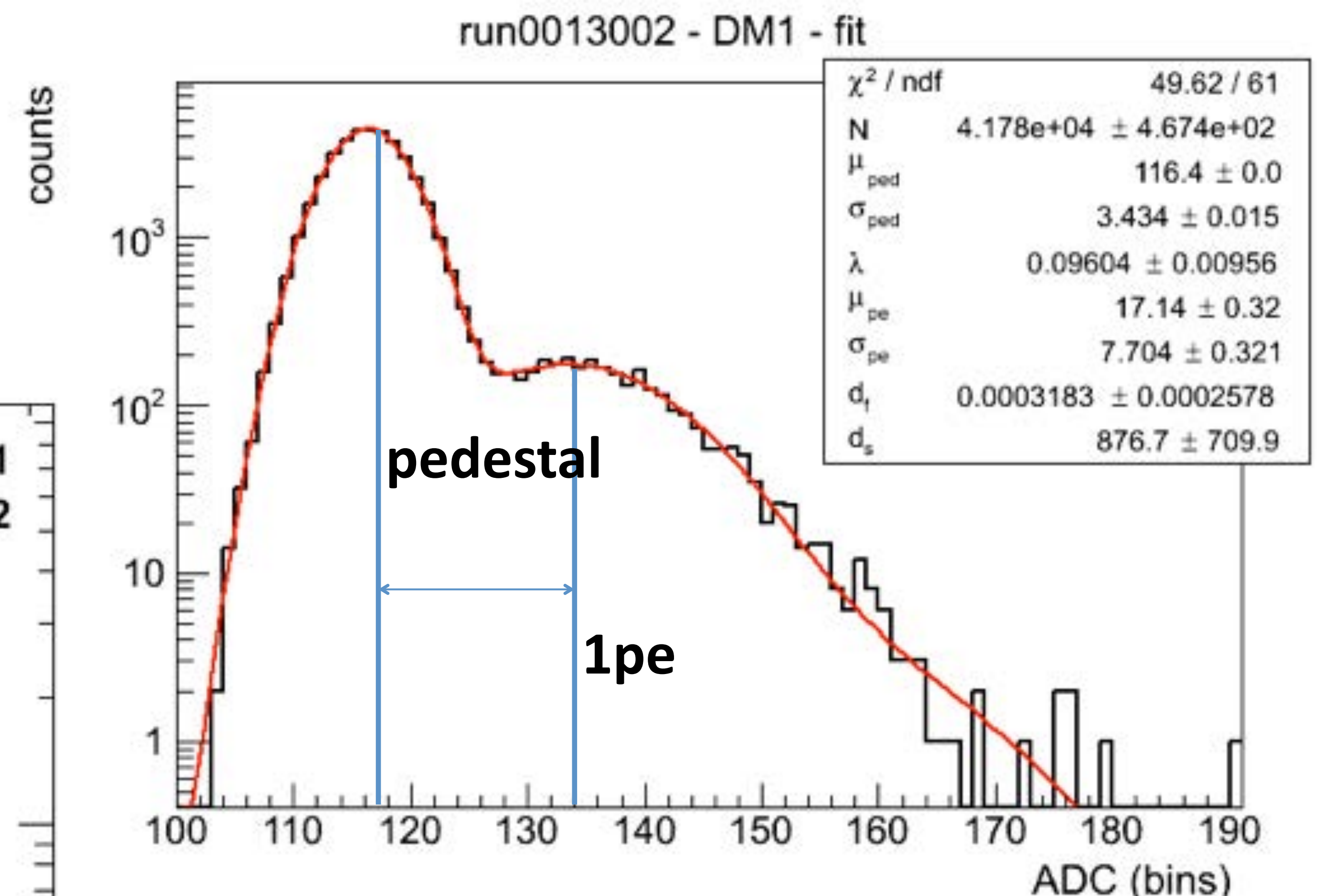


# Light Collection and Detector Resolution

- Detector resolution comparable to expected
- Determined from intrinsic contamination lines




DM-Ice Collaboration
arXiv:1401.4804v1



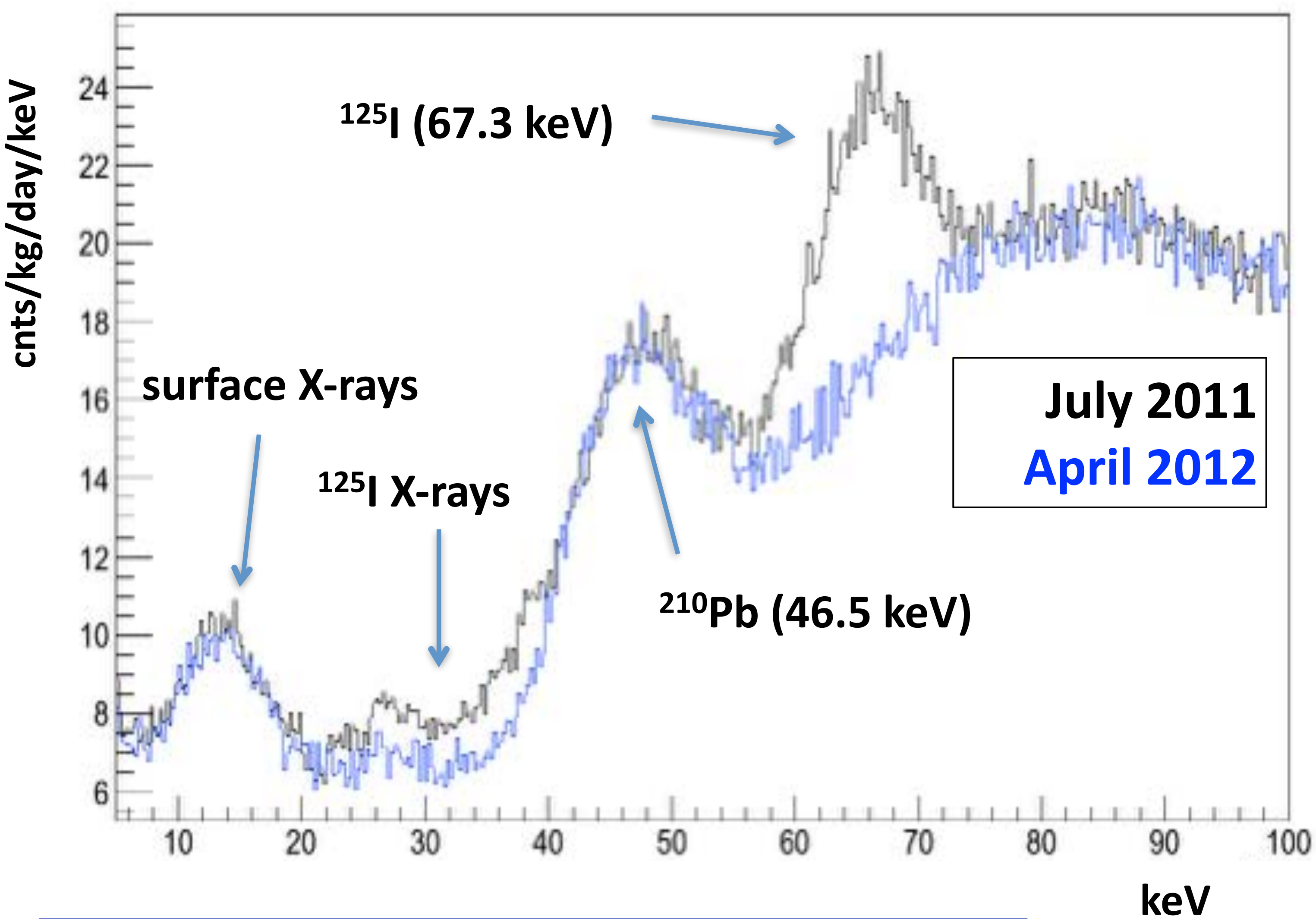

**Normalize the energy to keV using the energy calibration**

**xtal-1 = 5.9 pe/keV**

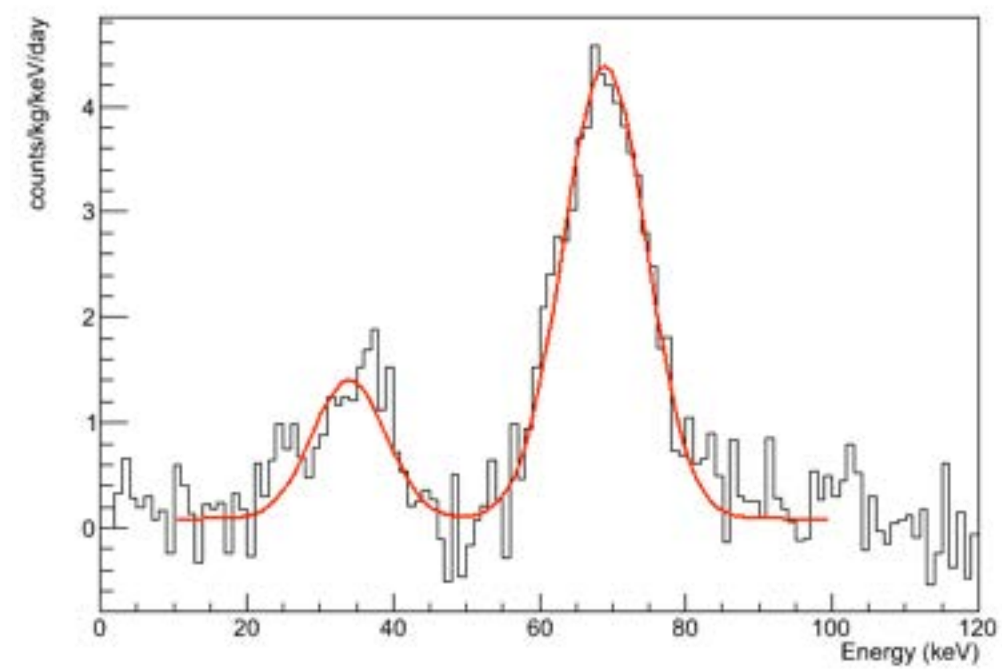
**xtal-2 = 4.3 pe/keV**

# Cosmogenic $^{125}$I (in the NaI crystal)

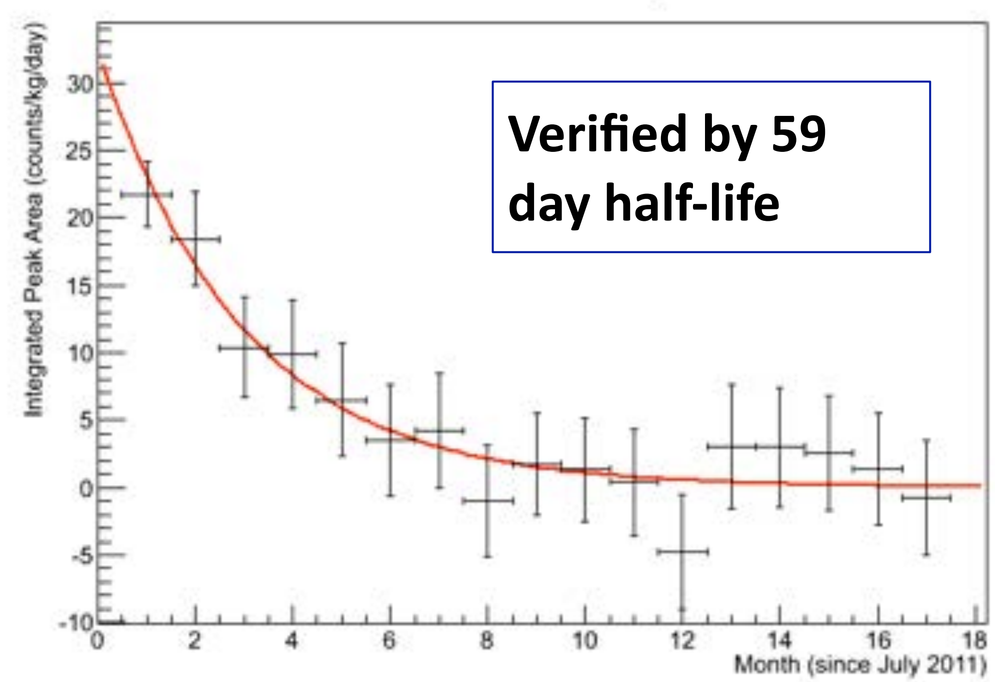
**Decay of $^{125}$I**




**July – April Residual**




$^{125}$I Peak Decay

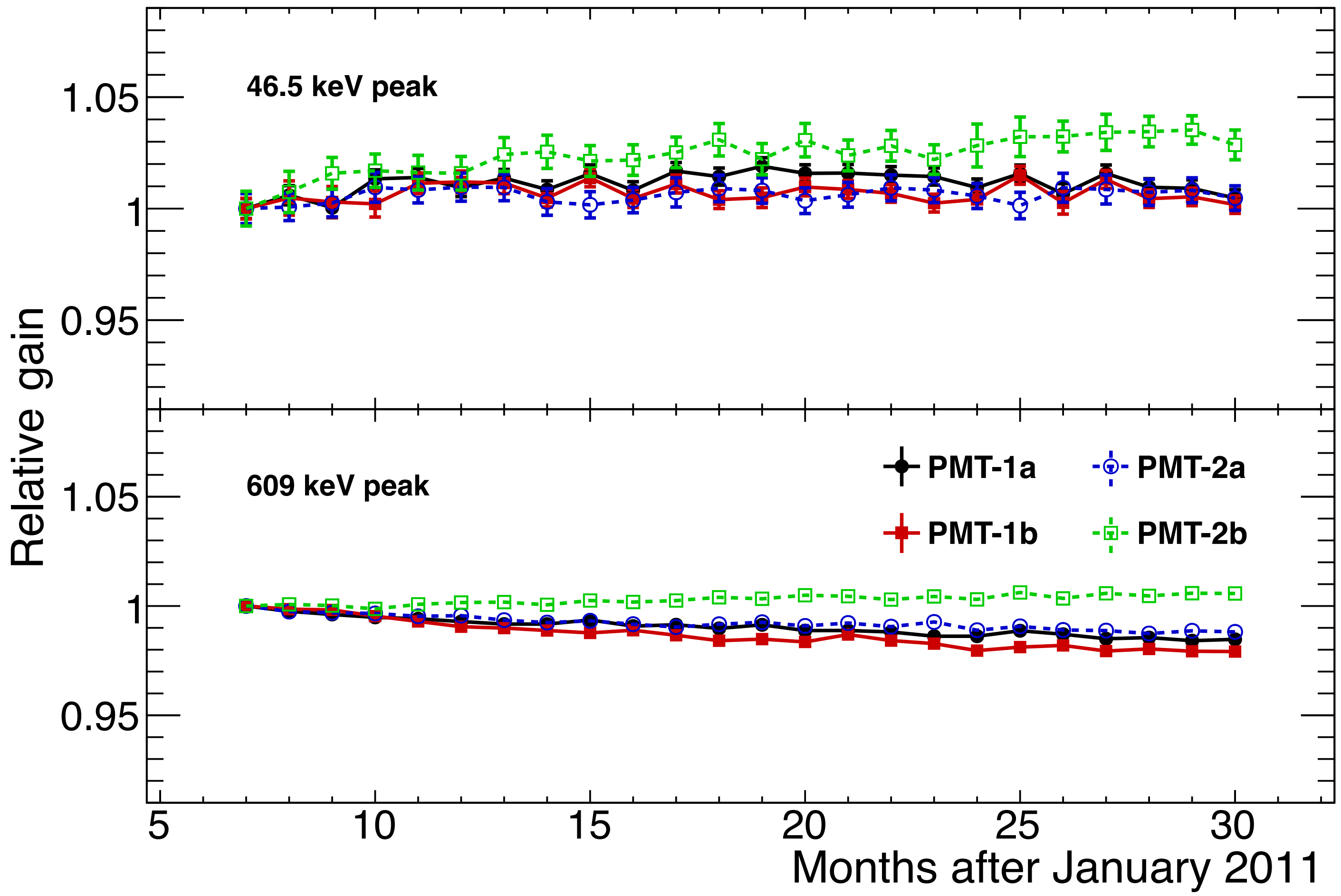



**Cosmogenic lines verify our energy calibration; this is particularly useful for the prototype since we do not have an in-ice source.**

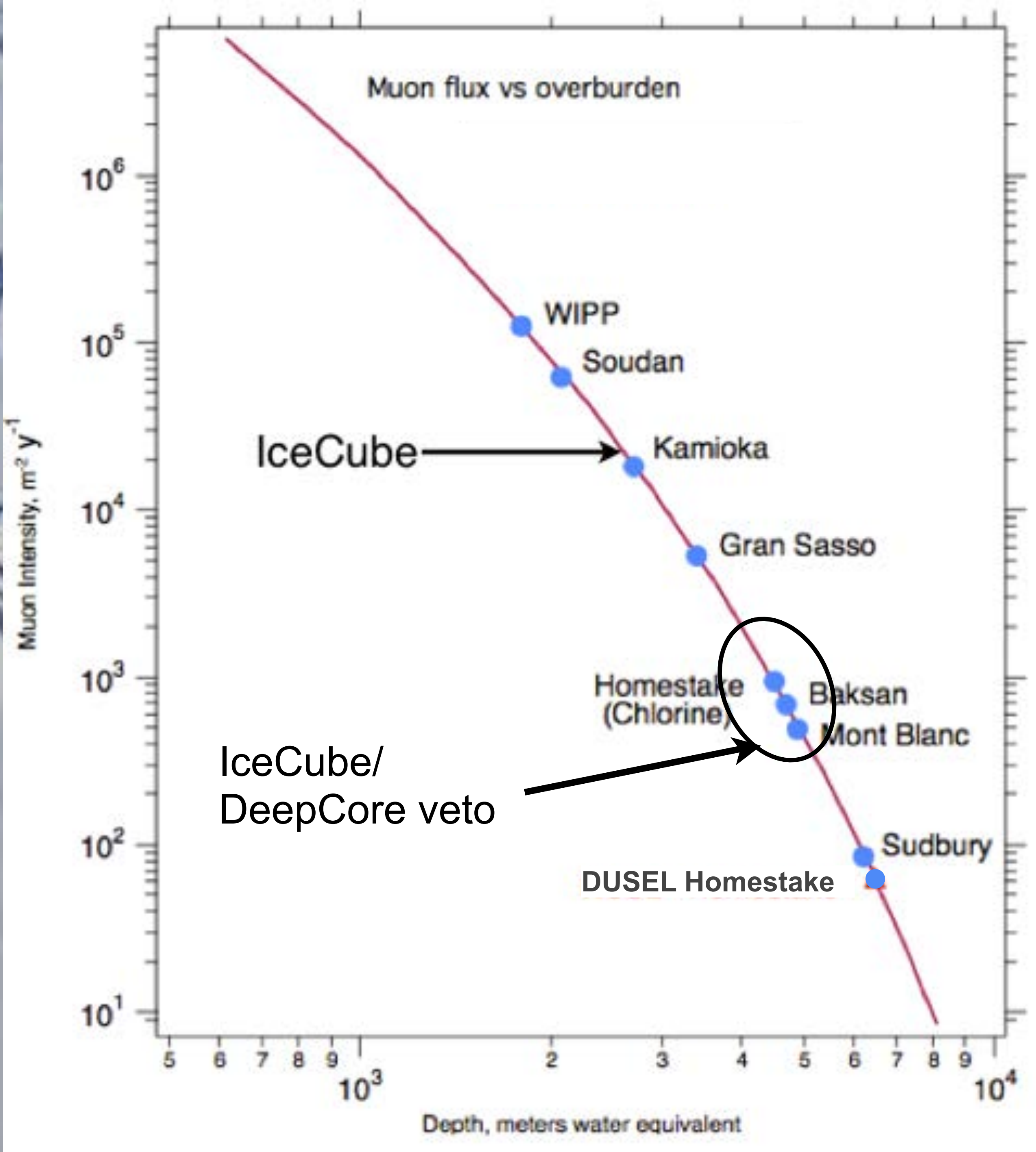
DM-Ice Collaboration
arXiv:1401.4804v1

# Gain Stability

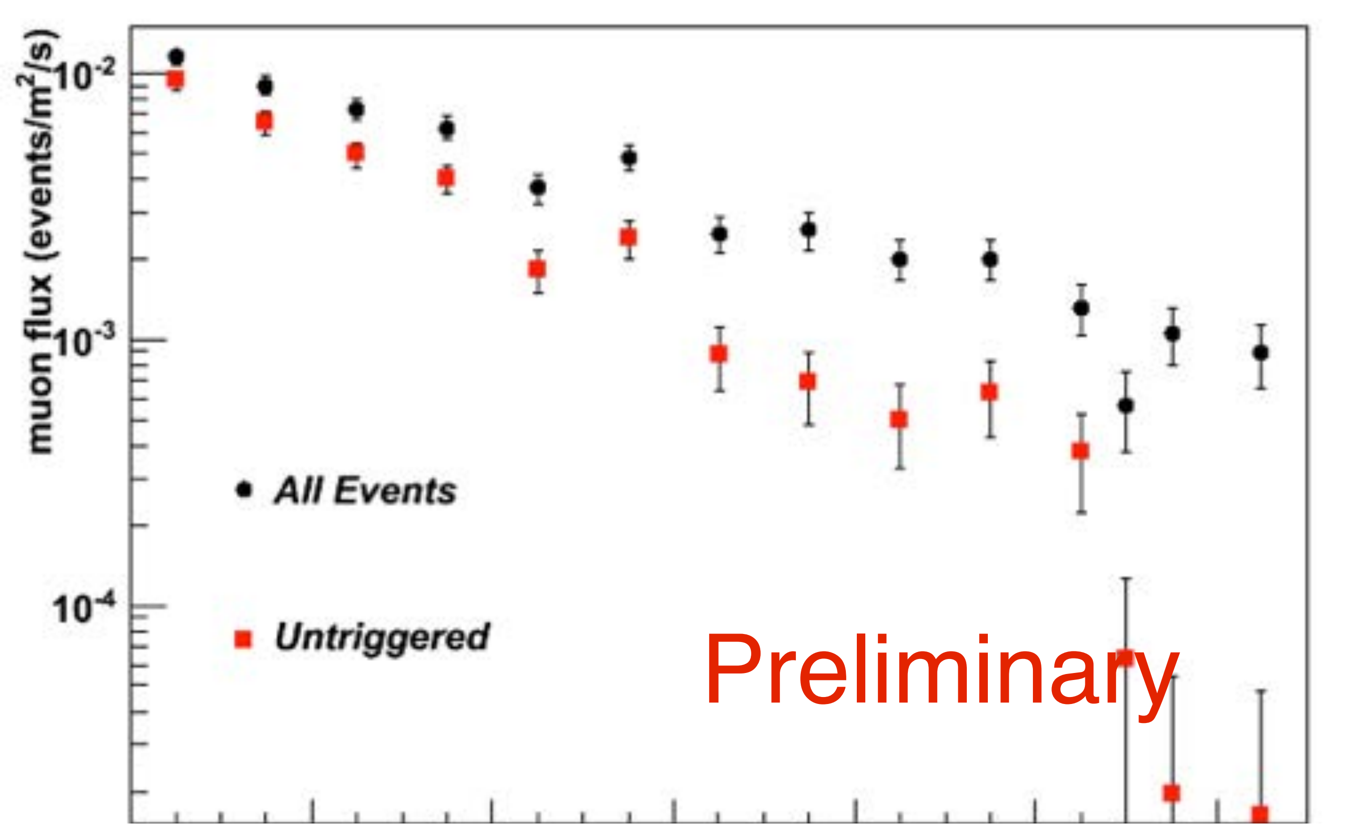
- Detector calibration is stable to 1% over 18 months.
- 2% decrease over 24 months in light collection (peak position) observed at 600 keV in 3 PMTs
- No observable change in calibration at 45 keV



# Antarctic Ice: Overburden at -2500 m (2200 m.w.e.)

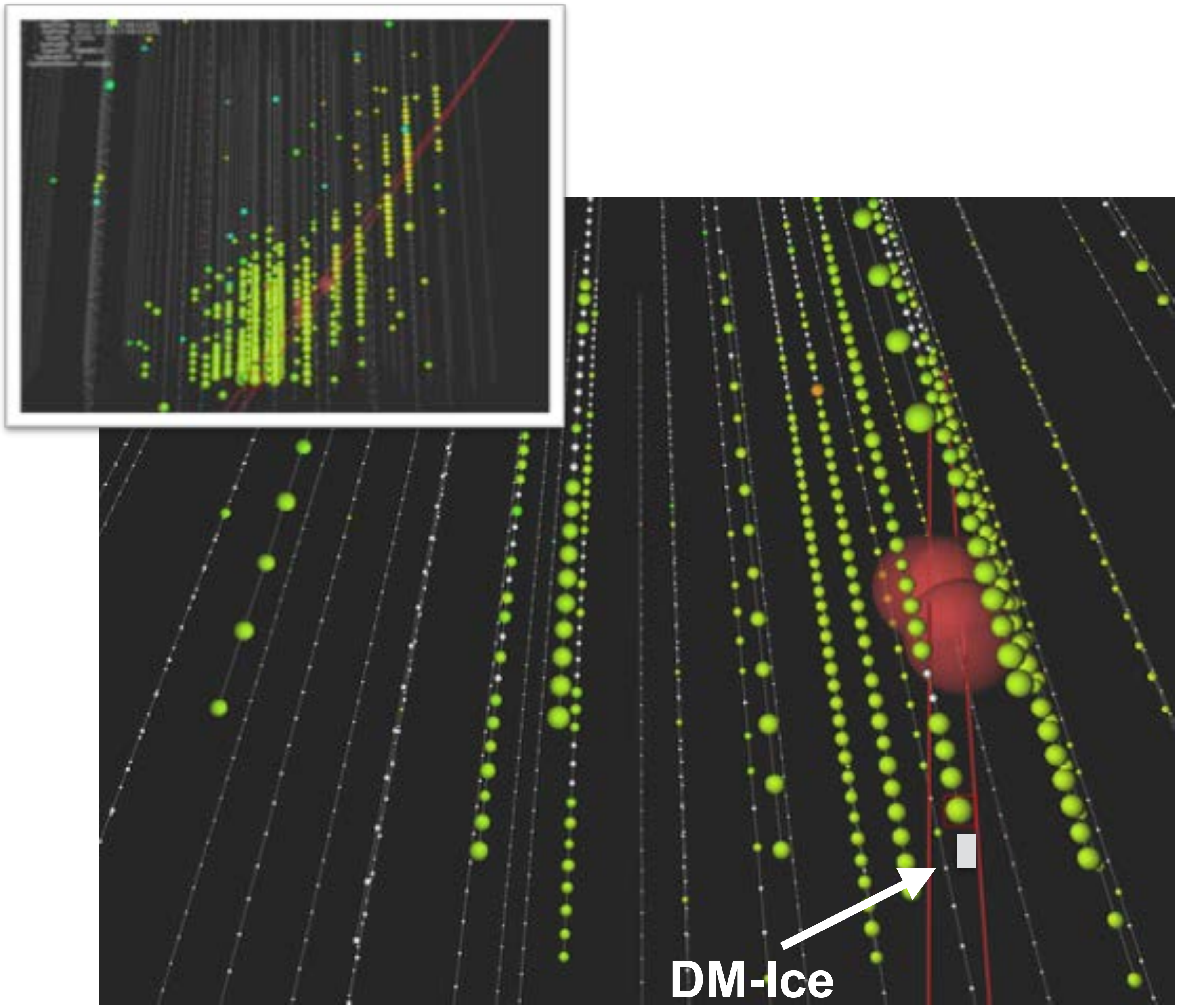



- ~85 muons/m$^2$/day at bottom of IceCube (2/day for DM-Ice17)
- IceCube/DeepCore veto reduces rate by ~1-2 orders of magnitude.




Muon flux vs. depth in the ice, total and those untriggered by IceCube/DeepCore.

# IceCube - DM-Ice Coincidence




December 2012 – Event #14
2012-12-21 RunID: 121431, EventID 79868923

Events that trigger both DM-Ice and IceCube Found!

Muon rate in DM-Ice (appear as mip): 2/day

66 found in 11 months of muon stream.
sDST will give more

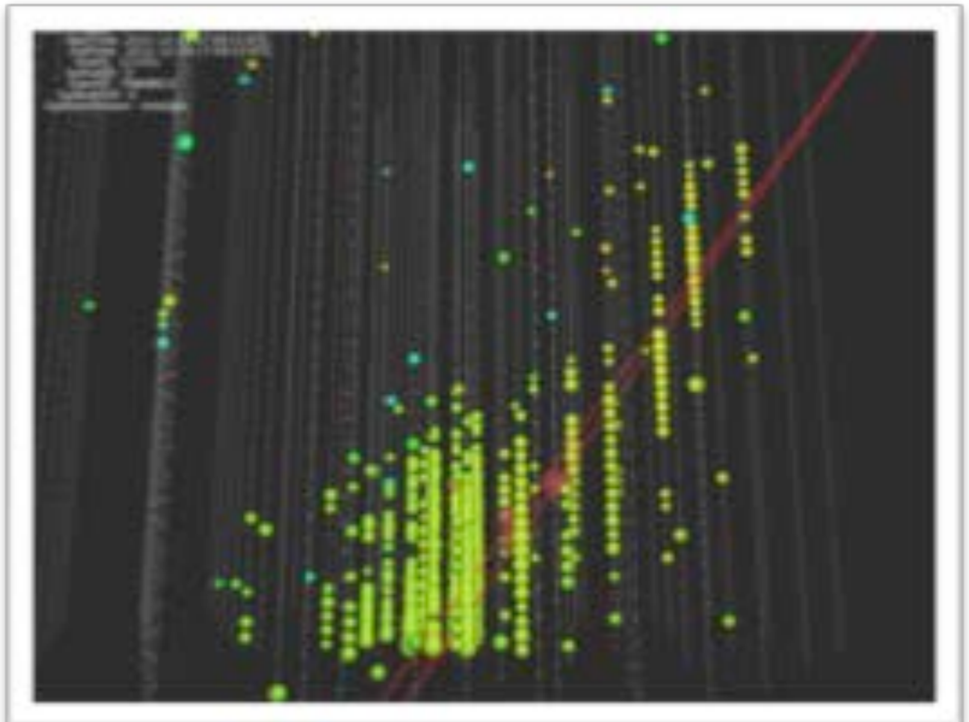
**Implications:**

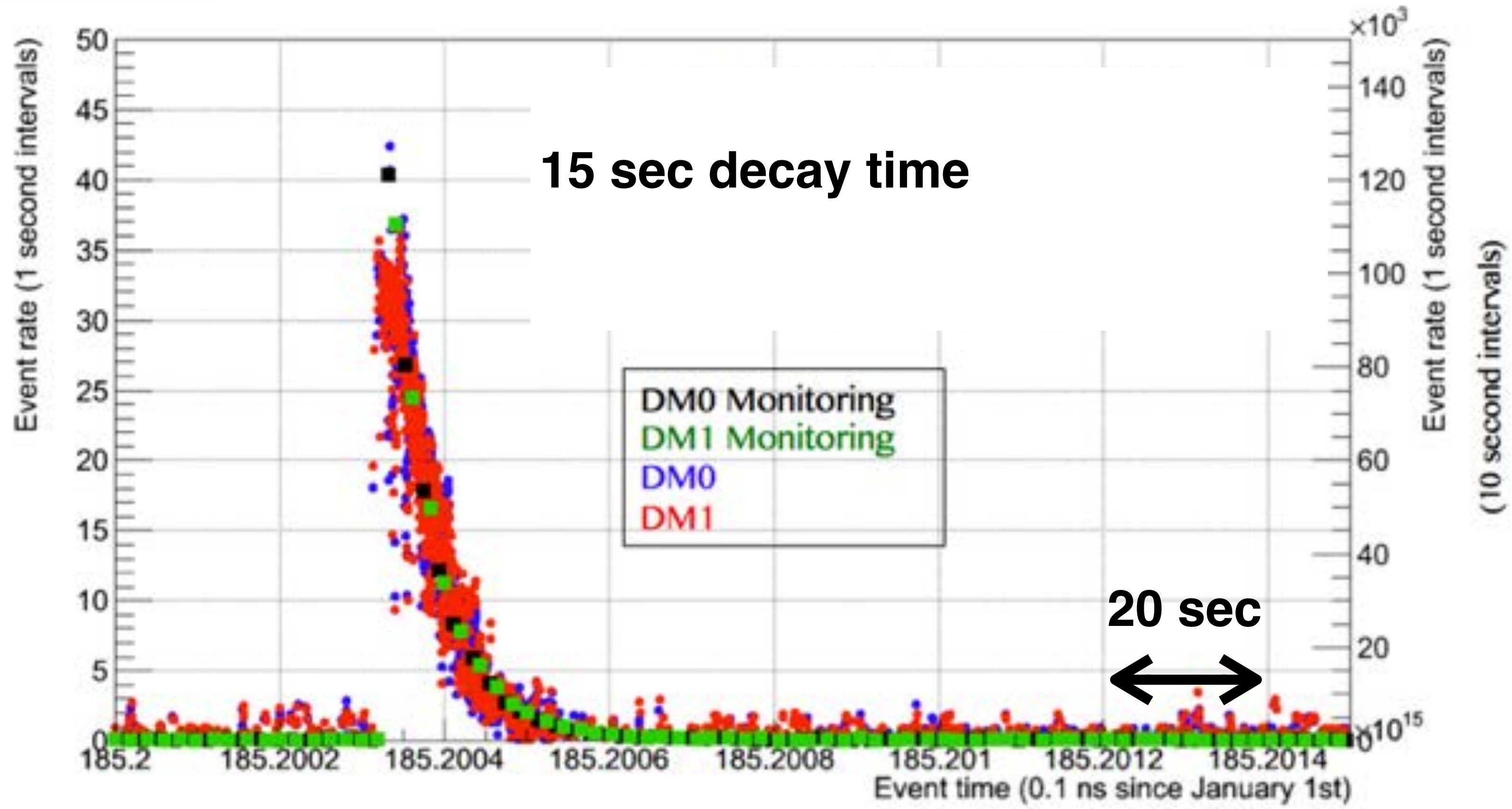
- 5-inch position resolution in two locations
- Energy threshold studies
- DM-Ice trigger for IceCube?

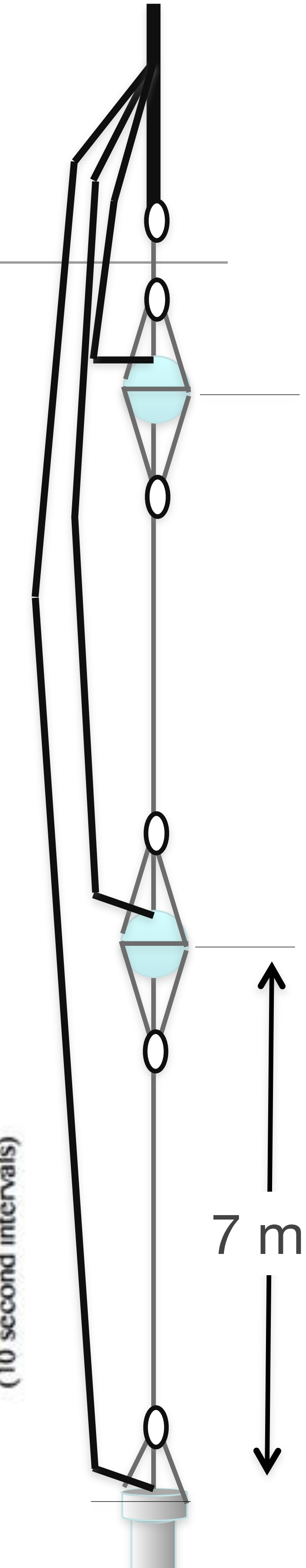
# December 2012- Event #14


DOM 60 highlighted

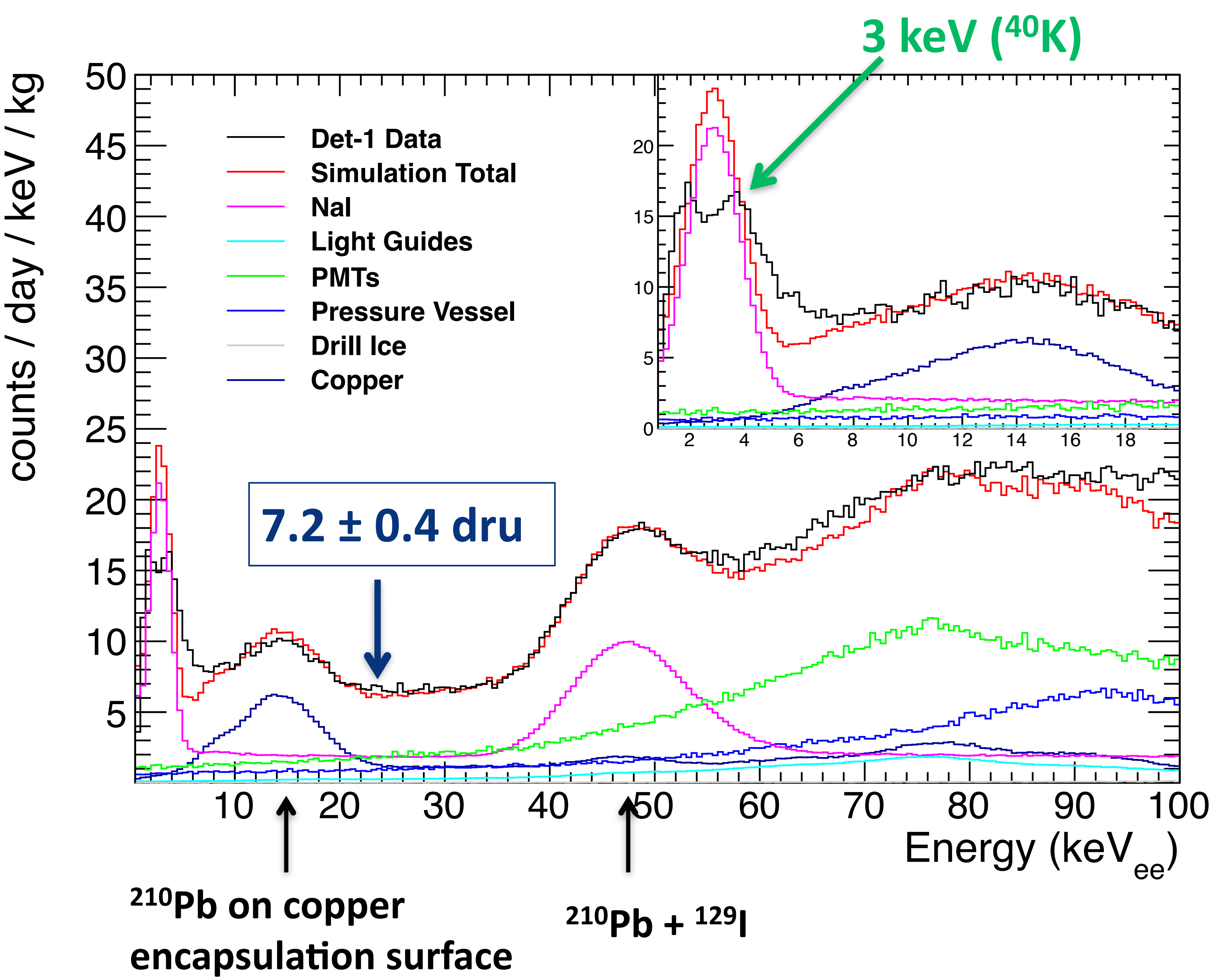
# Muon-activated events





# Energy Spectrum < 100 keV




- Events in ROI dominated by $^{40}$K, $^{210}$Pb, and $^{129}$I in the crystal.
- $^{210}$Pb in simulation tuned to match data
- $^{40}$K level is from beta-shoulder ~ 800 keV (not 3 keV).
- 3 keV peak from $^{40}$K observed
- Understanding efficiencies below 8 keV is key
- Controlling contaminations on nearby surfaces crucial
- c.f. DAMA = 1 dru

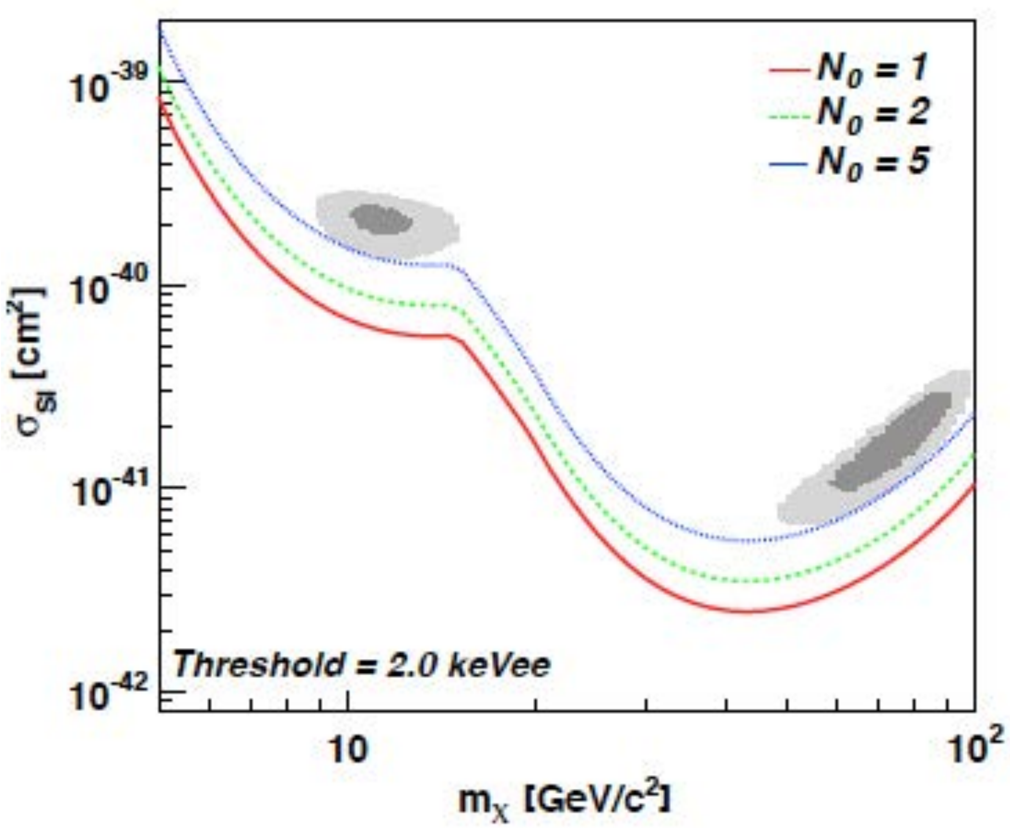
arXiv:1401.4804v1

# Testing DAMA's Dark Matter Claim

Definitive (5σ) detection or exclusion with

arXiv:1106.1156

- 500 kg-yr NaI(Tl) (DAMA x 2 yrs)
- same or lower threshold (< 2 $keV_{ee}$)
- background < (DAMA x 5)




**500 kg·year NaI detector sensitivity**
(2 - 4 keV) with bgd of 1, 2, and 5 cnts/keV/kg/day.

| | | DM-Ice17 | NAIAD-scale | DAMA-scale |
|---|---|---|---|---|
| | Years | 17.0 kg | 44.5 kg | 250 kg |
| x8 DAMA background | 1 | 0.45 | 0.72 | 1.71 |
| | 3 | 0.77 | 1.25 | 2.96 |
| | 5 | 1.00 | 1.61 | 3.82 |
| | 7 | 1.18 | 1.91 | 4.52 |
| x4 DAMA background | 1 | 0.63 | 1.02 | 2.42 |
| | 3 | 1.09 | 1.77 | 4.18 |
| | 5 | 1.41 | 2.28 | 5.40 |
| | 7 | 1.67 | 2.70 | 6.39 |
| Double DAMA background | 1 | 0.85 | 1.37 | 3.26 |
| | 3 | 1.47 | 2.38 | 5.64 |
| | 5 | 1.90 | 3.07 | 7.29 |
| | 7 | 2.25 | 3.64 | 8.62 |
| DAMA background | 1 | 1.20 | 1.94 | 4.61 |
| | 3 | 2.08 | 3.37 | 7.98 |
| | 5 | 2.69 | 4.35 | 10.31 |
| | 7 | 3.18 | 5.14 | 12.19 |
| 1/10 DAMA background | 1 | 3.80 | 6.15 | 14.57 |
| | 3 | 6.58 | 10.65 | 25.24 |
| | 5 | 8.50 | 13.75 | 32.59 |
| | 7 | 10.06 | 16.27 | 38.56 |

**Additional Information by lowering the threshold below 2 keV.**

# NaI Powder R&D

- **From simulation, internal backgrounds dominate, particularly 3 keV $^{40}$K**
- **DAMA's crystals (NIMA 592 (2008) 297– 315) :**
  - **$^{238}$U : 1 - 10 ppt**
  - **$^{232}$Th : 1 - 10 ppt**
  - **$^{nat}$K : < 20 ppb**
- **NAIAD (DM-Ice17) crystals : 5 - 10x DAMA bkg**
  **(PLB 616 (2005) 17–24)**

**32" diameter NaI Crystal**

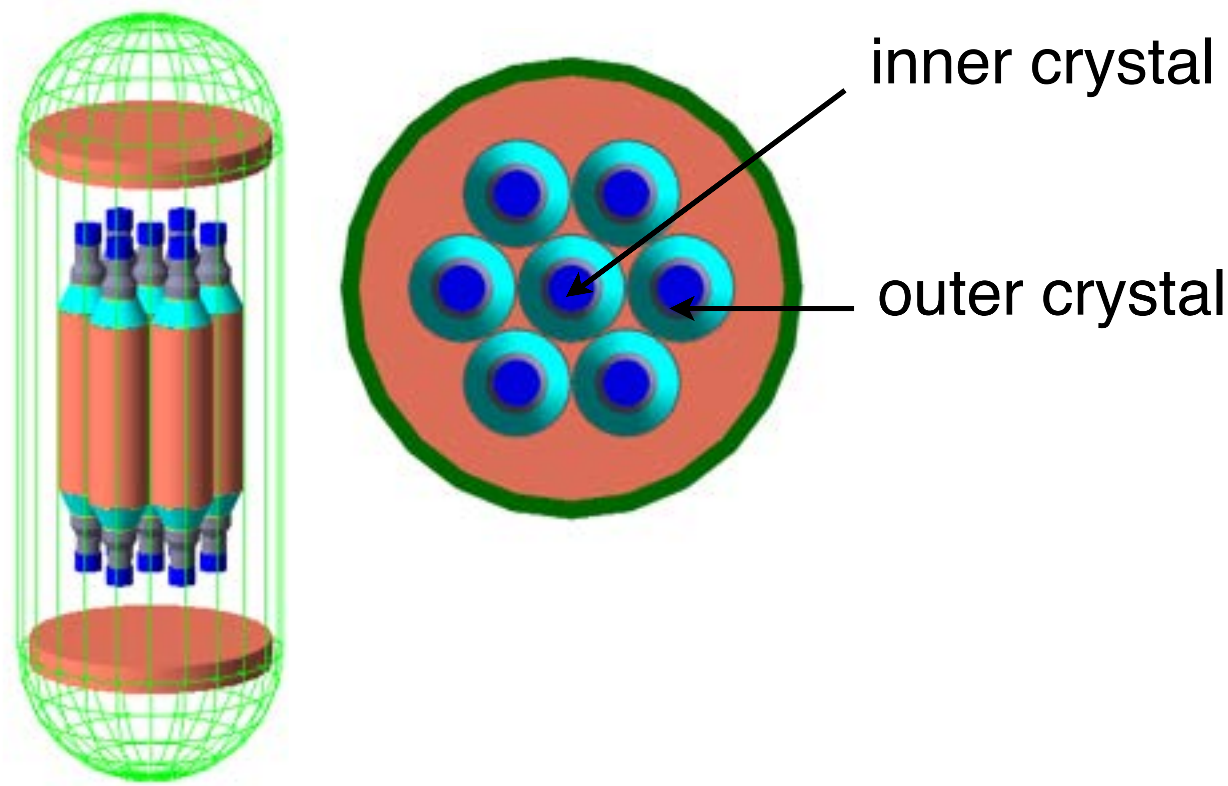
| Manufacturer | Form | Measurement | 238 | 232 | nat |
|---|---|---|---|---|---|
| Saint Gobain | Powder | DAMA (HPGe) | < 20 | < 20 | < 100 |
| Saint Gobain | Crystal | DAMA/LIBRA | 0.7 - 10 | 0.5 - 7.5 | < 20 |
| Saint Gobain | Crystal | ANAIS-0 | 6.1 | 3.2 | 410 |
| Bicron/Saint Gobain | Crystal | NaIAD/DM-Ice | 20 | 20 | 650 |
| Sigma-Aldrich | Powder (standard grade) | DM-Ice (HPGe) | 40 | 89 | 440 |
| Sigma-Aldrich | Powder (astro grade) | DM-Ice (HPGe) | 63 | < 95 | < 126 |
| Sigma-Aldrich | Powder (astro grade) | A-S (ICPMS) | - | - | ~ 4 |
| Alpha-Spectra | Powder | DM-Ice (HPGe) | < 100 | < 200 | < 120 |
| Alpha-Spectra | Powder | ANAIS-25 (HPGe) | < 55 | < 130 | < 90 |

- **Also working with SICCAS (Shanghi)**

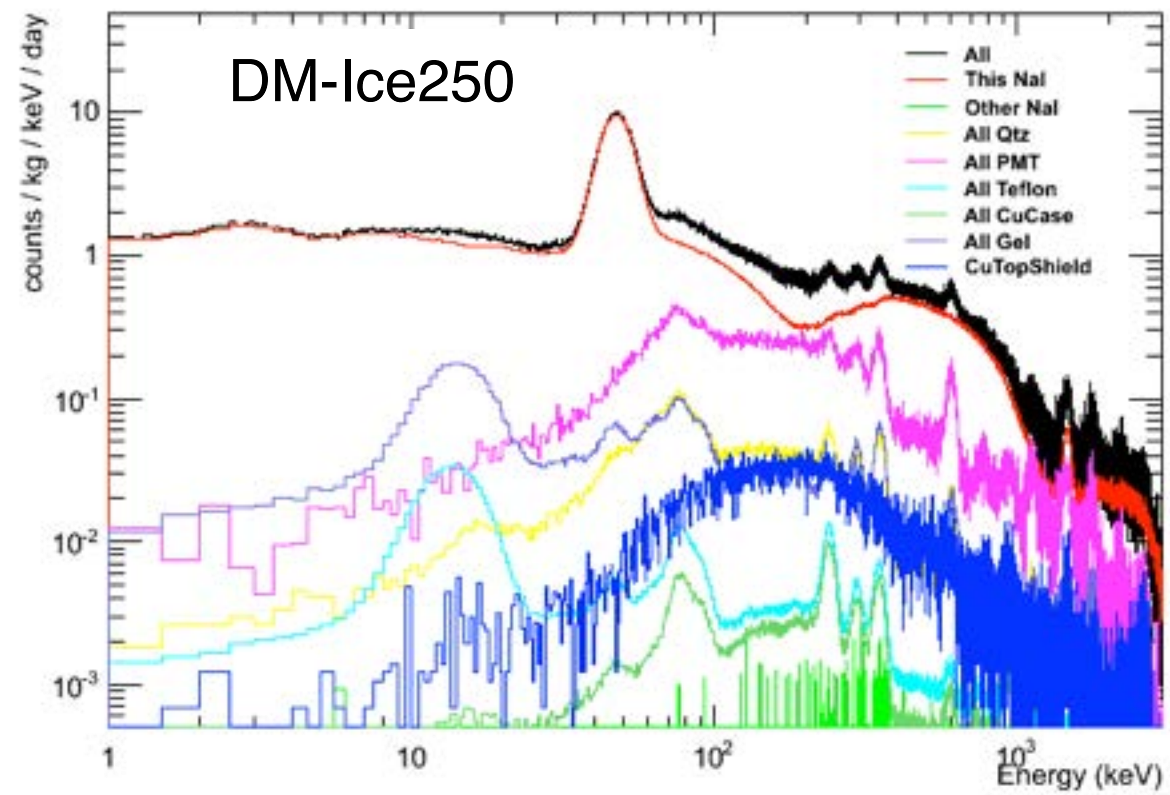
**Technical challenge == a method to measure K < 100 ppb level**
- **ICPMS → < 10 ppb ?**

# DM-Ice250 Simulations

## Close-Packed Detector Array




Inner Crystal Vetoed Spectrum




## Sensitivity to DAMA Modulation Signal

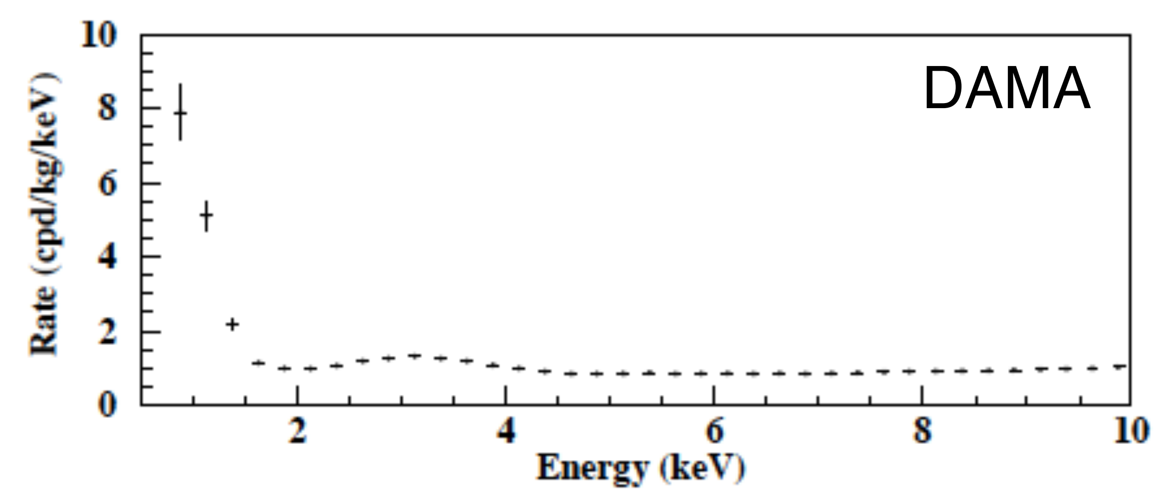
assume 225 kg exposure/yr (90% livetime)

**1 year:** 3.3σ
**2 years:** 4.6σ
**3 years:** 5.7σ

Based on MC sample of modulated signal, using same binning and analysis method as DAMA, fit to fixed phase and period.

## DM-Ice250 Background

**2-6 keV region:** 1.75 dru average
(worst case with veto)



# New Low-Background NaI(Tl) Crystals

Development of NaI(Tl) detectors with Alpha Spectra, Inc (ASI) in CO, USA
Three groups work with Alpha Spectra: DM-Ice, ANAIS, KIMS.
Communication and sharing of R&D results

- 2 x 18 kg crystals from Alpha Spectra are at Fermilab MINOS near hall for testing.

- If these crystals confirm specifications, total of 250 kg can be grown and encapsulated as detectors at ASI in less than 12 months.

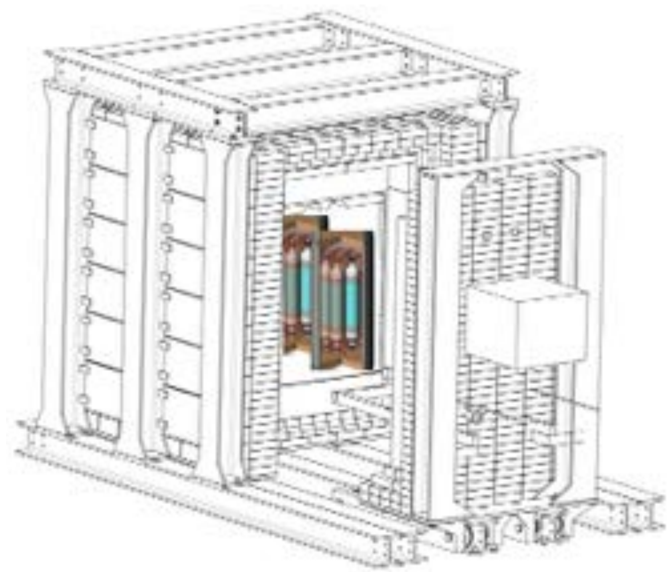
Backgrounds are within acceptable levels for an experiment with 2 counts/day/keV/kg.
Sufficient to test the DAMA signal at > 5σ with 3 years of data.

# Next Steps for DM-Ice

**DM-Ice17**

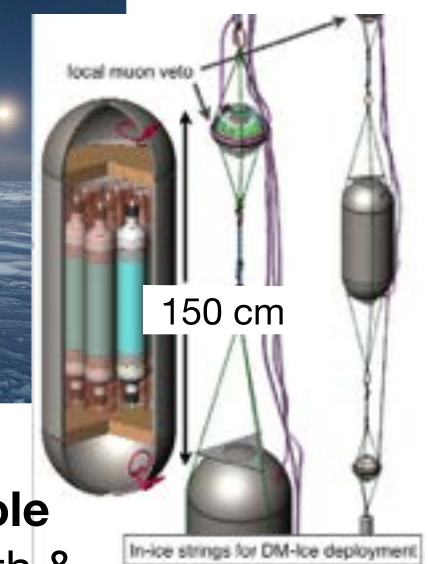
**Operating since 2011**
17 kg of NaI(Tl) at 2450m depth at South Pole

**DM-Ice 250 North**



**Northern Hemisphere Run**
portable 250 kg NaI(Tl) detector, first deployment in the Northern Hemisphere. Several sites can house DM-Ice

**DM-Ice 250 South**




**Deployment at South Pole**
if modulation seen in North & ice drilling becomes available

- NaI test crystals at Fermilab - verify their cleanliness
- Movable detector housing and electronics being finalized
- Northern deployment as the first step

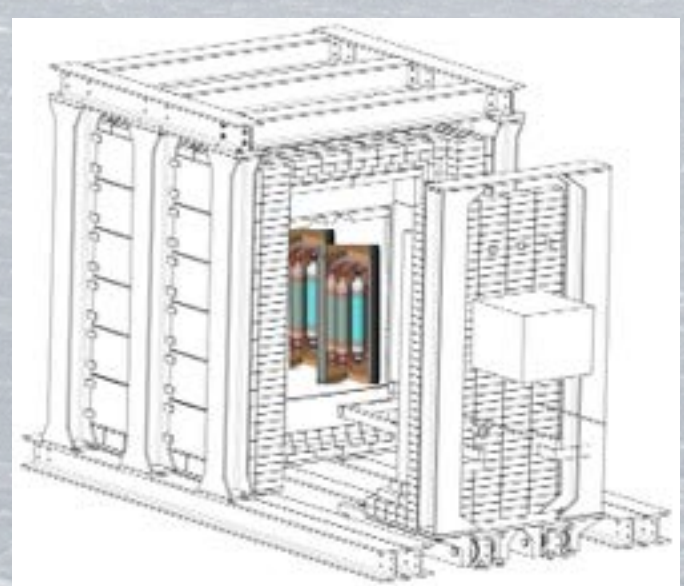
# Summary

**Directly test DAMA's assertion that the observed annual modulation is due to dark matter & understand its origin**

- Success installation and running of DM-Ice17 at the South Pole
- Background level in DM-Ice17 as expected and in agreement with simulations
- New NaI crystals to be delivered within 1 week
- Next: full-scale experiment w/ portable detectors to be deployed in the north, move south if signal observed.

**DM-Ice17**

**DM-Ice 250 North**



**DM-Ice 250 South**