DM-Ice

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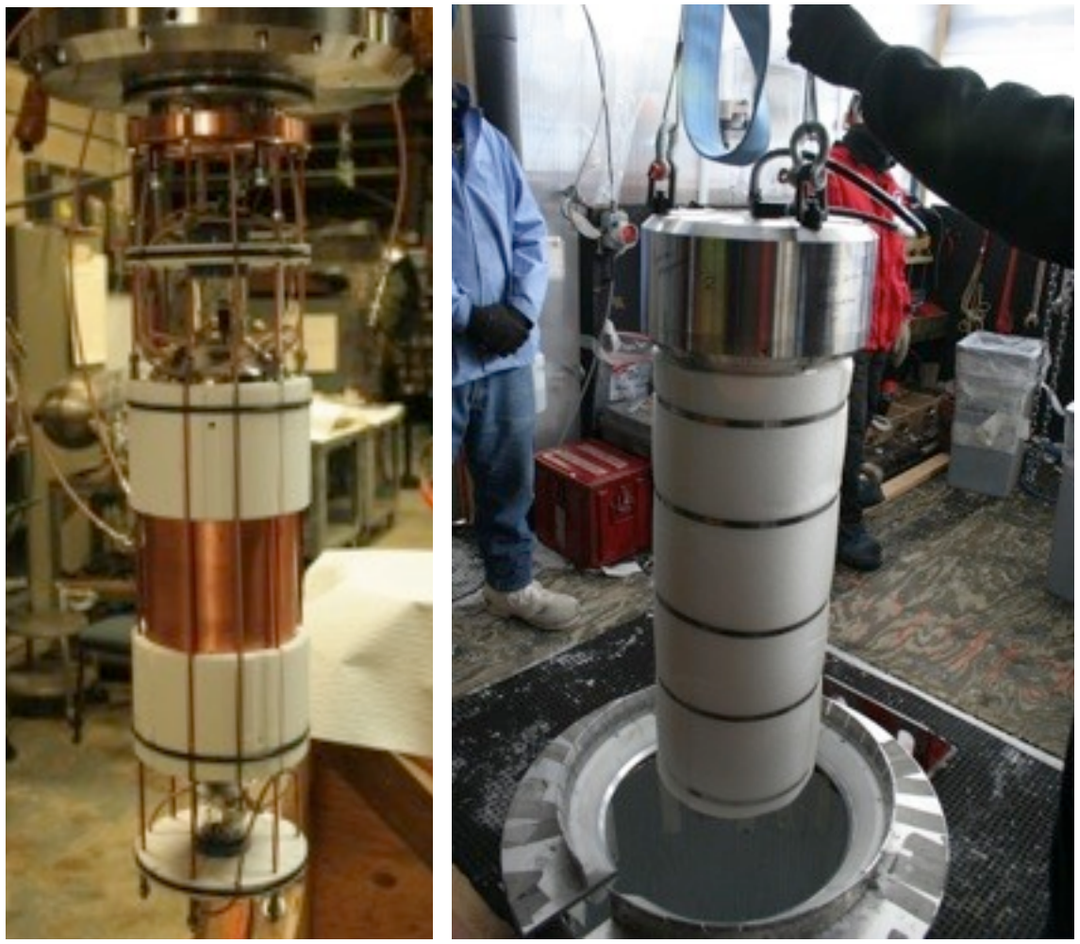
WISCONSIN ICECUBE PARTICLE ASTROPHYSICS CENTER

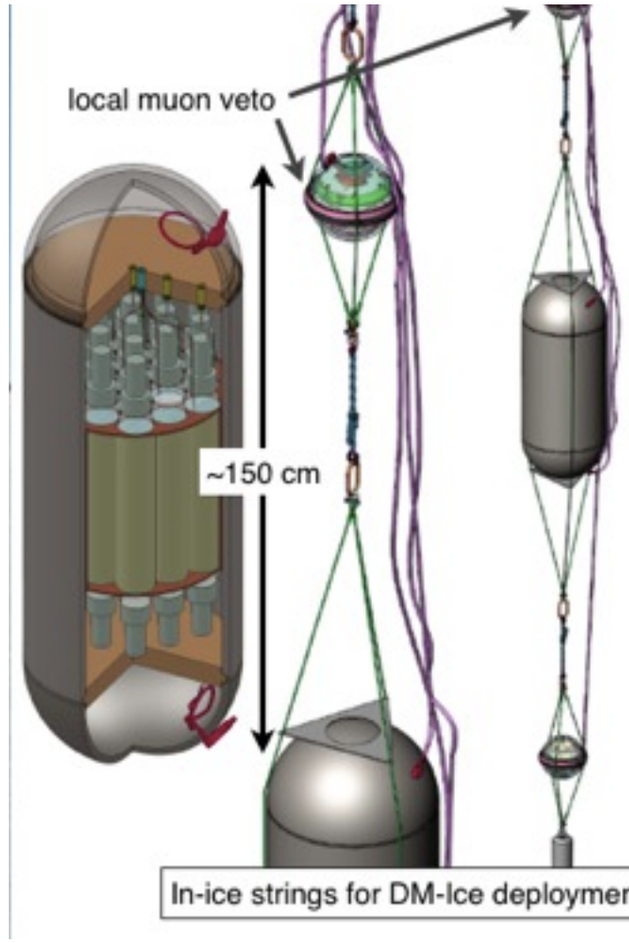
1. Experiment Status and Target Mass

Currently in Operation: DM-Ice17



17 kg of NaI(Tl), operation since 2011
Funding: NSF-Polar Programs &
NSF-CAREER for R&D
First results expected in Spring

Proposed Full-Scale: DM-Ice



250 kg of ultra-pure NaI(Tl)
Proposed deployment: Dec. 2015

2. Fiducial Target Mass

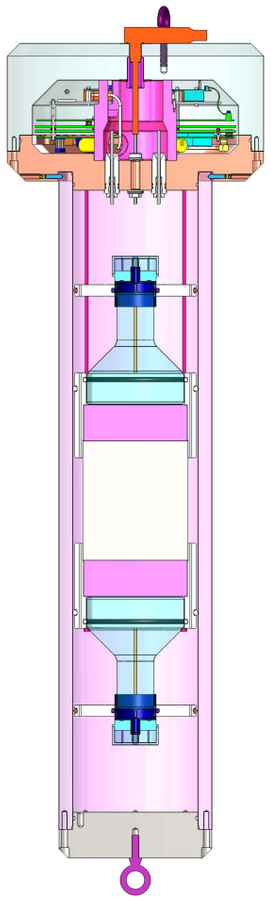
DM-Ice diameter is limited to ~65 cm by the ice drill.

DM-Ice17:

2 modules (pressure vessels)

5” dia x 5” long, 1 crystal / module

total mass: 17 kg of NaI(Tl)



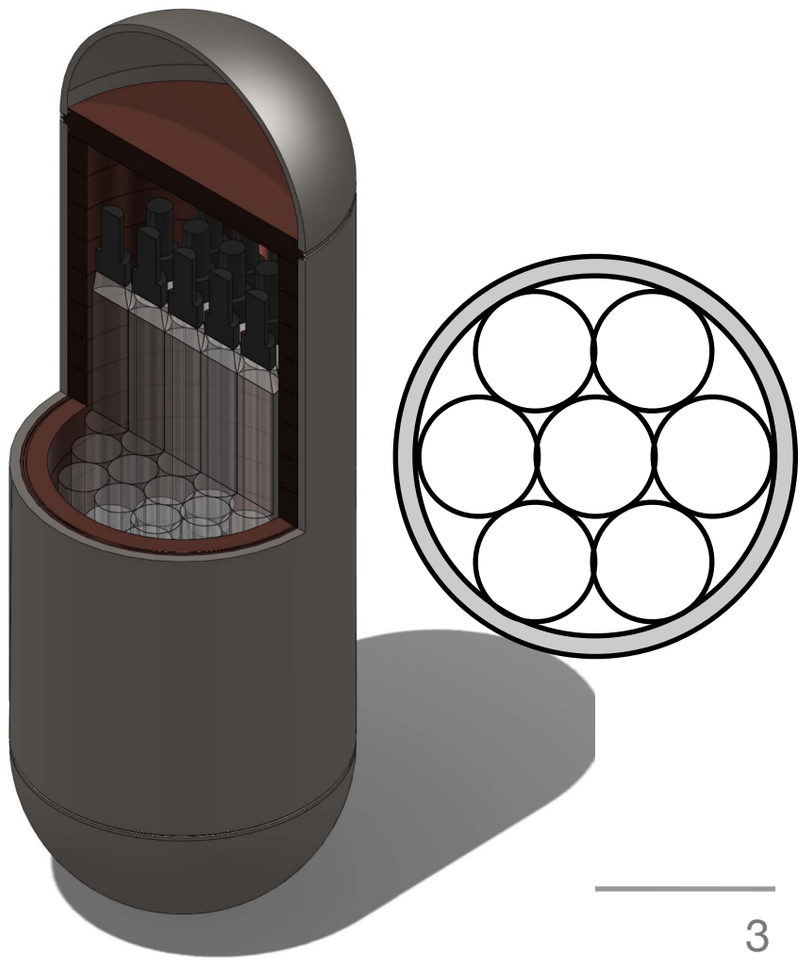
DM-Ice:

2 modules

5” dia x 15” long, 7 crystals/module

total mass: 250 kg of NaI(Tl)

Multi-crystal events veto.



3. Backgrounds

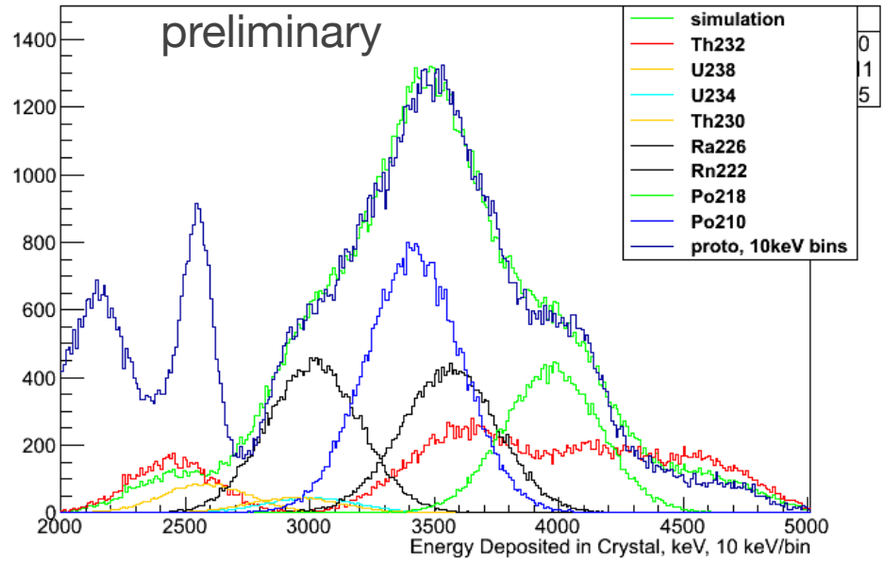
Going from DM-Ice17 to DM-Ice

- Background goal: < 1 cpd/keV$_{ee}$/kg in 2 - 10 keV$_{ee}$ (factor of 10 reduction)
- Contamination levels in DM-Ice17 estimated from in-ice data and radio-assay, verified by simulation
  - Dominant background in DM-Ice17: ^{40}K & ^{210}Pb in the crystals
  - Surrounding ice is extremely clean, drill ice is clean enough
  - Ultra-clean crystals are under development (see F. Calaprice's talk)
  - Cleaner PMT, Pressure Vessel, & Quartz are available
  - Direct muon interaction contribute O(10^{-5}) below other backgrounds
    - Muon monitor & tag with IceCube

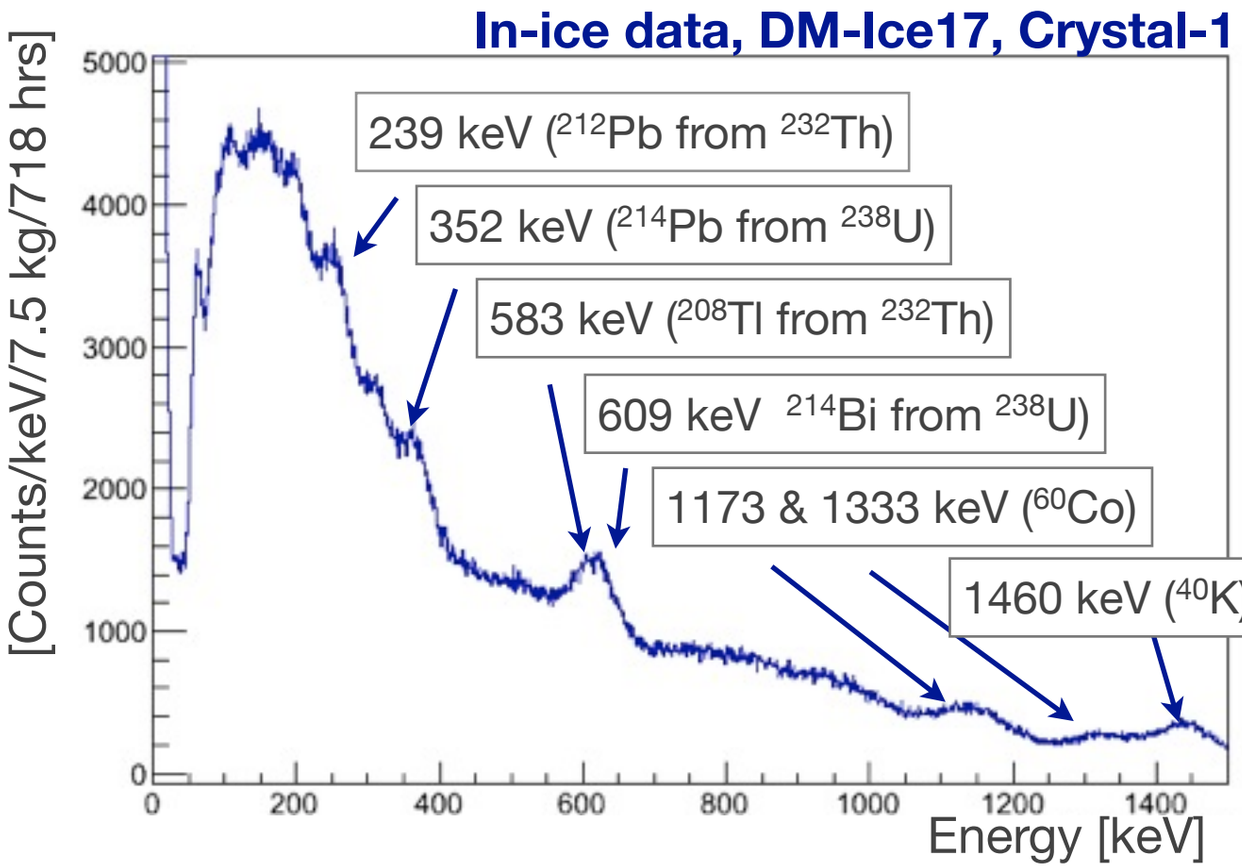
Crystal contamination in DM-Ice17 & DAMA

	DM-Ice17	DAMA
^{nat}K	500 ppb	< 20 ppb
^{232}Th	50 ppt	0.5 - 7.5 ppt
^{238}U (upper part of chain)	7.5 ppt	0.7 - 10 ppt
^{238}U (below Pb-210)	2 mBq/kg	5 - 30 μBq/kg

Alpha region in DM-Ice17 vs. Simulation



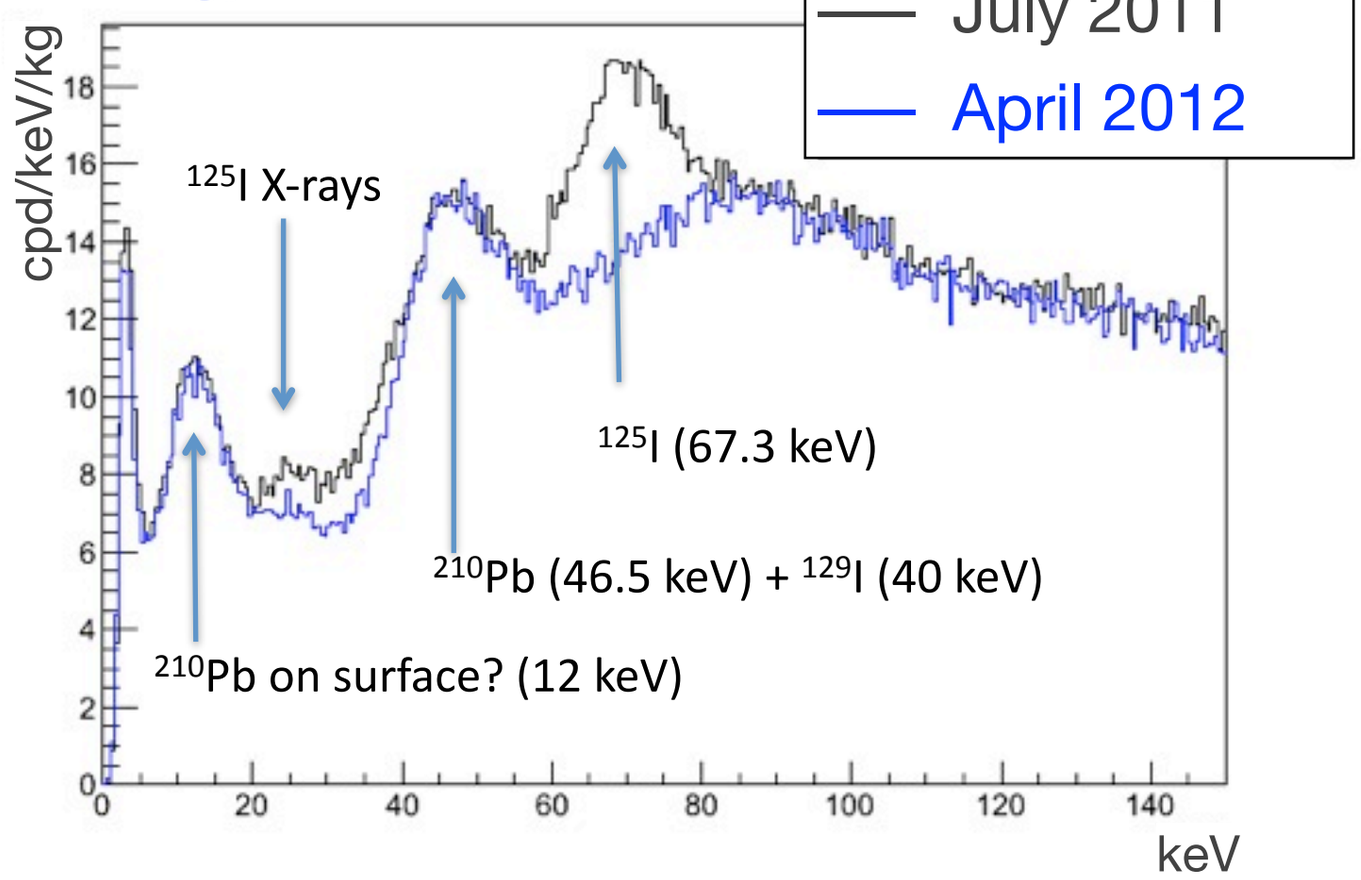
Backgrounds and Calibration: DM-Ice17



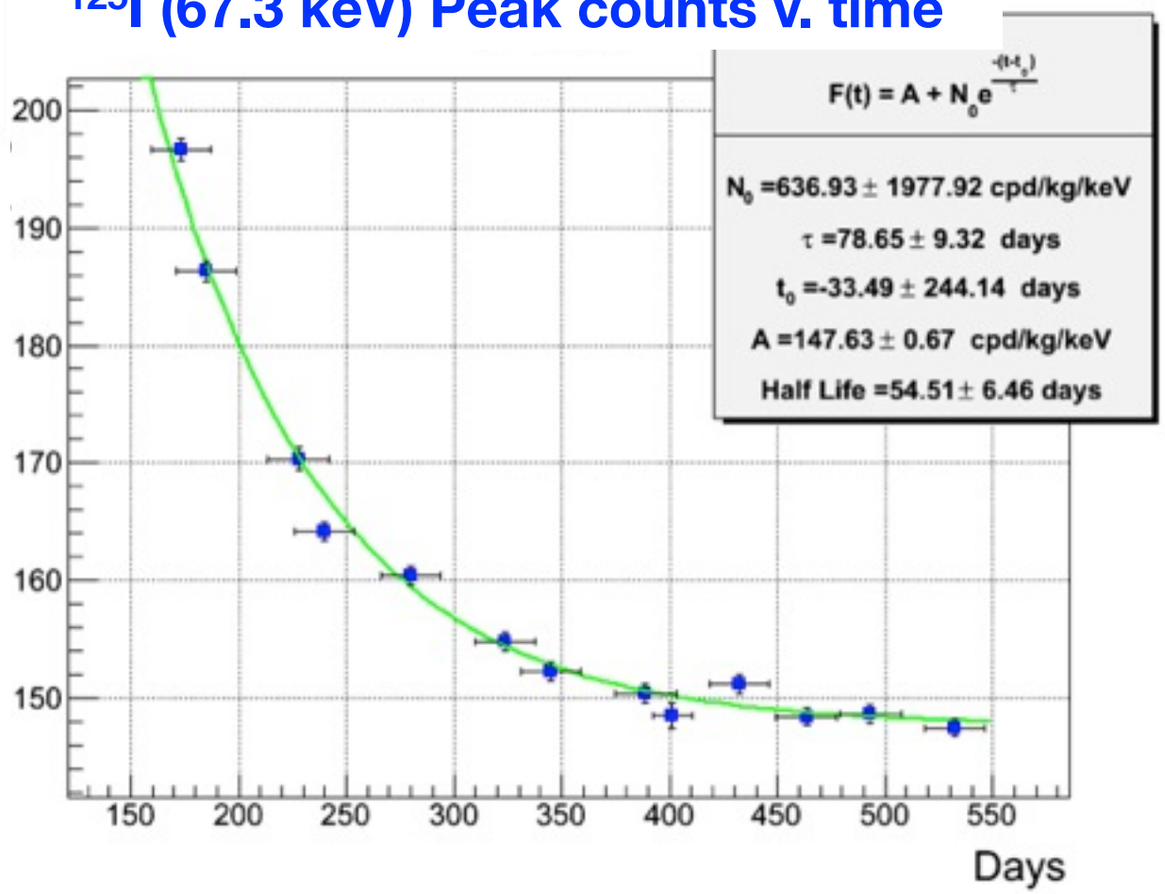
- Energy = integral(waveform)
- Detectors calibrated using internal lines
- Spectra compared & verified with source calibration at Madison and Boulby
  - ^{207}Bi (569.7 & 1063.66 keV)
  - ^{60}Co (122.06 & 136.5 keV),
  - ^{57}Co (1173.34 & 1332.50 keV)
- Calibration stable over >18 months

Low Energy Spectrum

Energy Spectrum < 150 keV



^{125}I (67.3 keV) Peak counts v. time

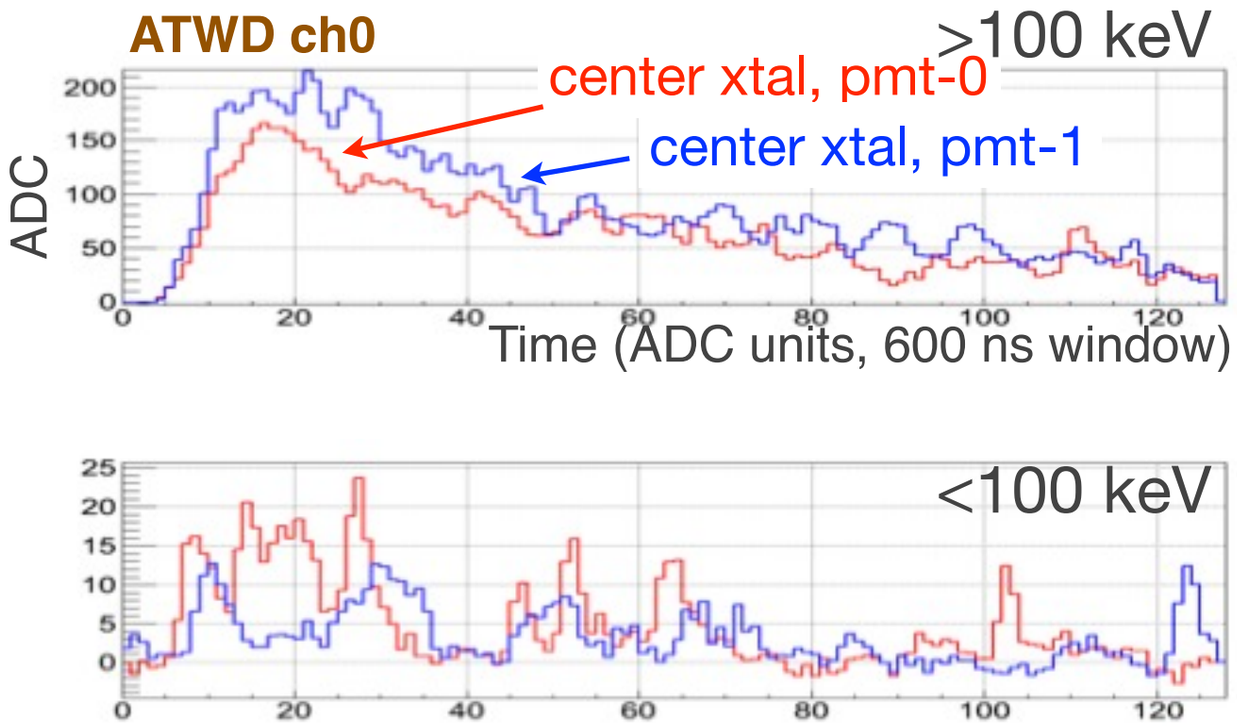


- 7 - 10 cpd/keV$_{ee}$/kg between 8 - 30 keV$_{ee}$.
- Low energy region calibrated with internal lines from Pb-210, I-125, & I-129
- Cosmogenic activation of ^{125}I observed with $T_{1/2}$ = 59.4 days
- K-40 line at 3.2 keV also visible.

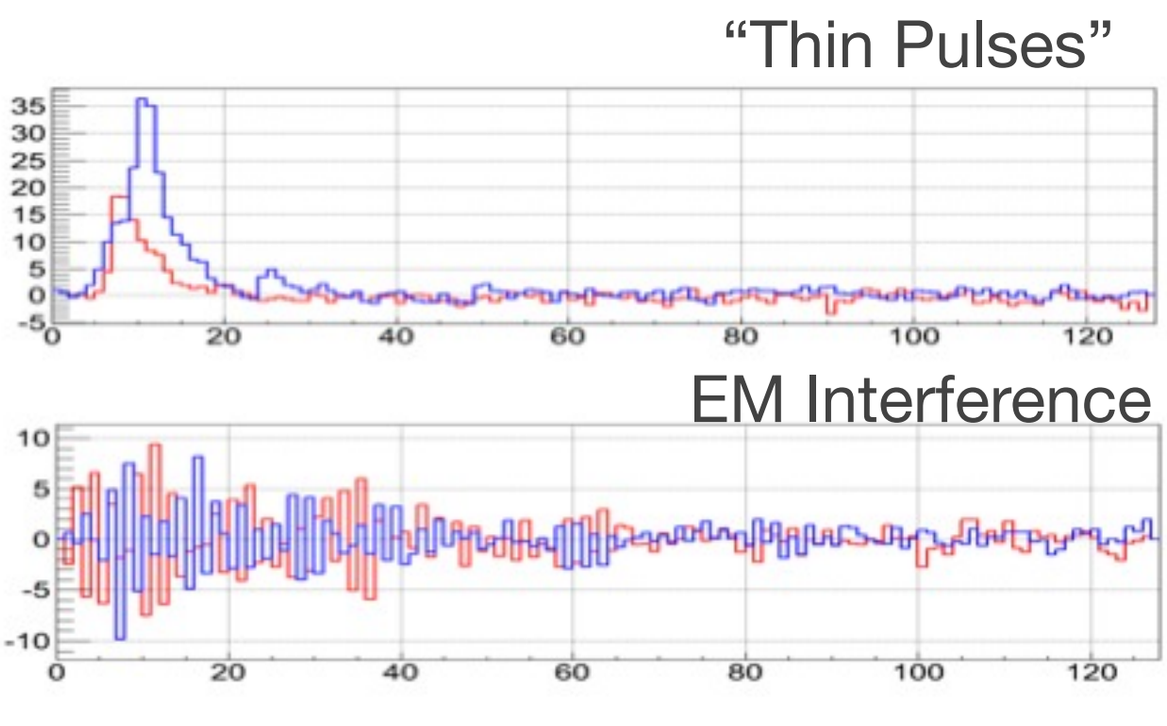
4. Detector Discrimination

- We currently use PSD to eliminate instrumental effects, e.g. “thin-pulses” that seem to originate in the PMTs in the ROI, but not used in physics events.
- At higher energies, it is possible to use PSD discriminate between gammas, alphas, and nuclear recoil. In the energy region of interest, PSD is not effective and will not be used.

Physics Events



Instrumental Events



5. Energy Threshold

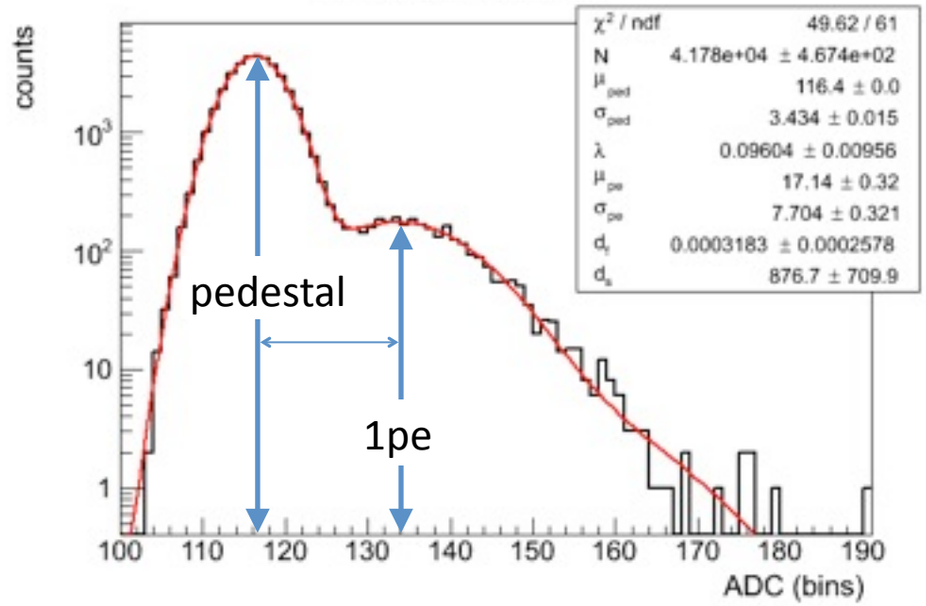
DM-Ice Goal:

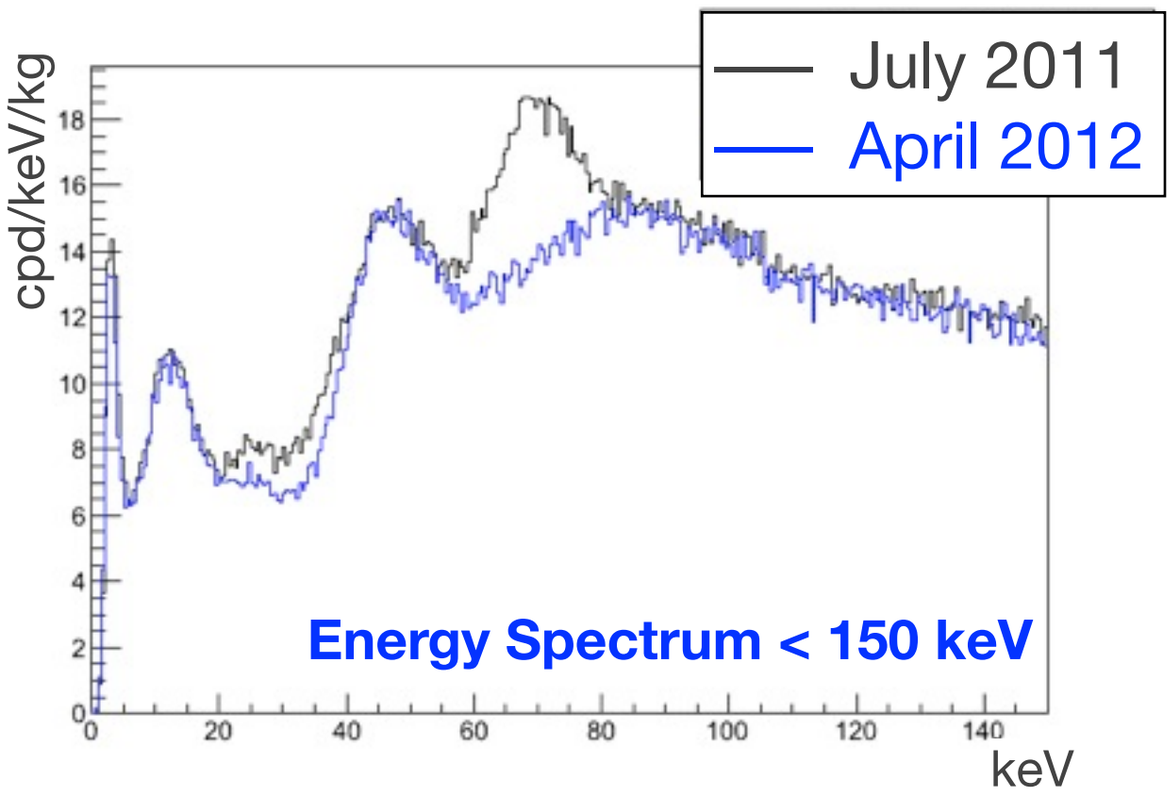
- < 2 keV_{ee} threshold

DM-Ice17:

- Analysis threshold: 8 keV_{ee} is robust, analysis in progress down to ~ 2 keV_{ee} with single crystals
- Light collection: 5 - 6 pe/keV
- Each PMT triggered at fraction of pe

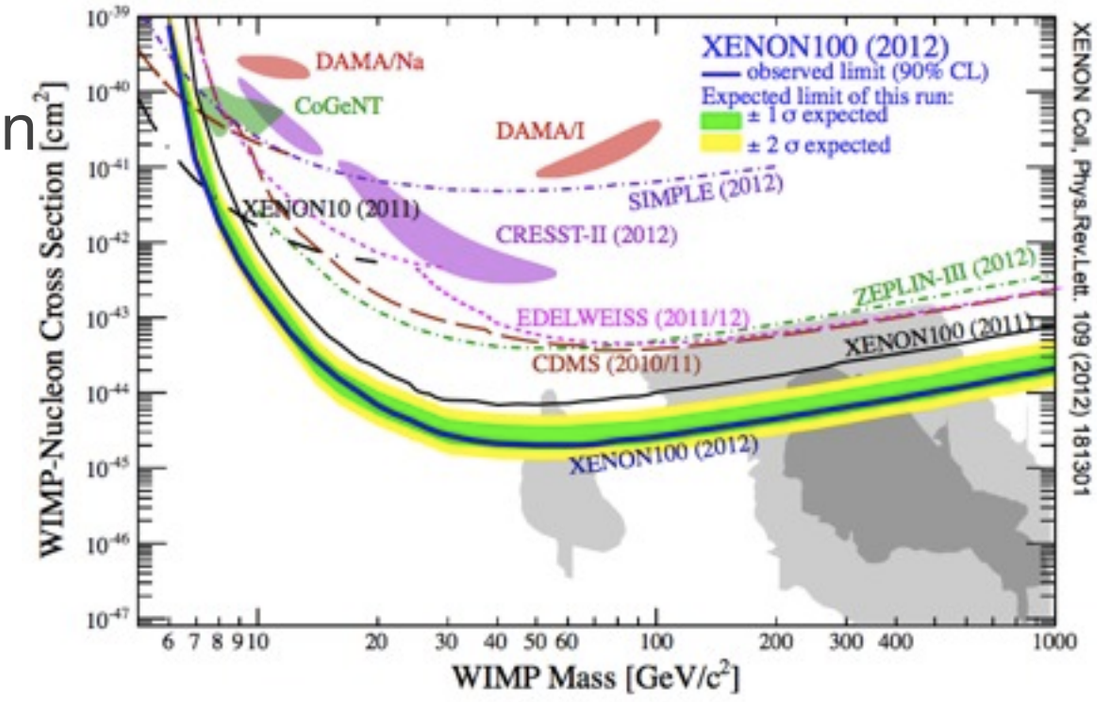
single photo-electron spectrum

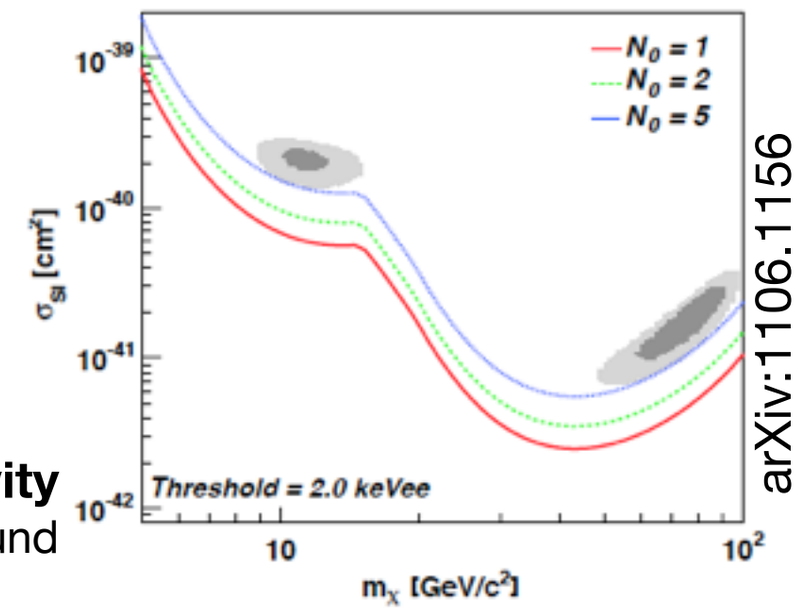




6. Sensitivity versus WIMP mass

- DM-Ice goal: test DAMA's claim for detection of DM annual modulation
  - Use the same target mass: NaI(Tl)
  - 500 kg-yr with (2-DAMA years)
  - < 5 cpd/keV/kg (DAMA: ~1 cpd/keV/kg)
  - Decouple possible seasonal effects from dark matter modulation

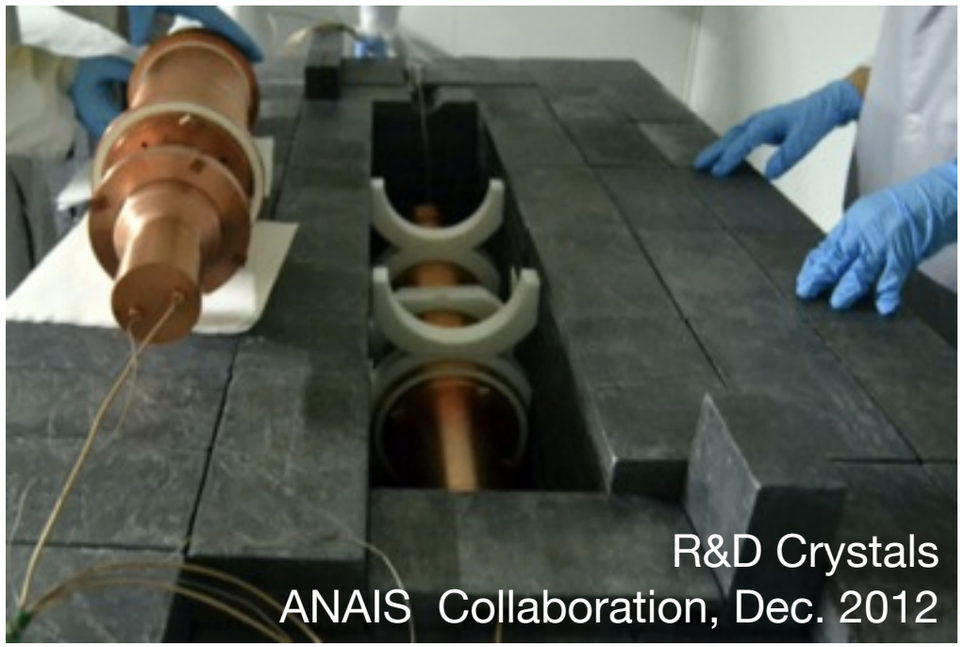




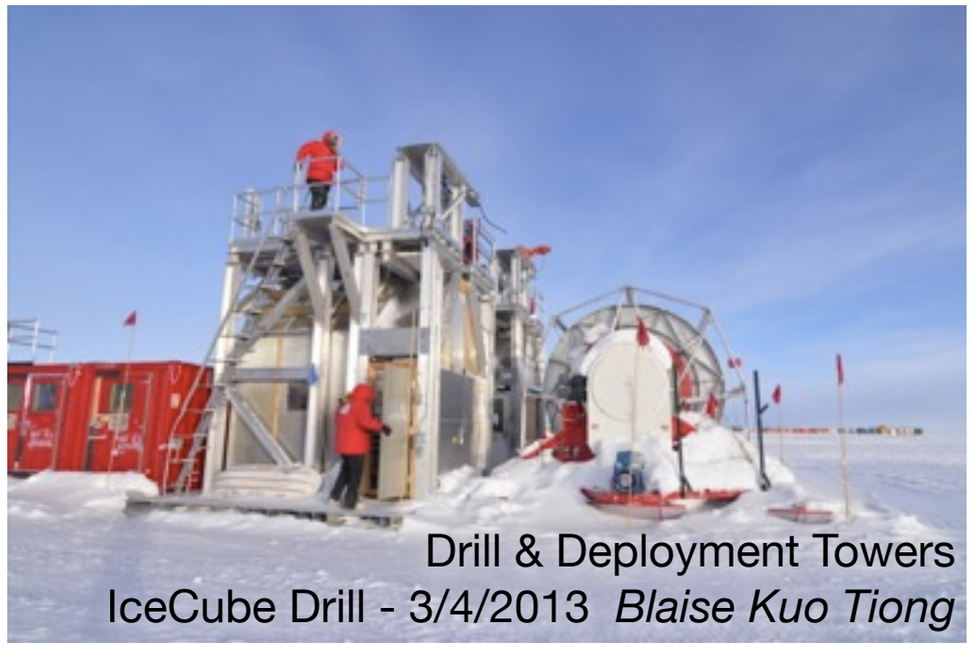
500 kg•year NaI detector sensitivity
(2 - 4 keV) with 1, 2, and 5 dru background

7. Experimental Challenges

- Development of Ultra-pure NaI powder and crystals by ANAIS, Princeton, KIMS, DM-Ice... (see also F. Calaprice's talk)
  - ultra-pure developed
  - crystals grown w/ ~40 ppb potassium
  - currently tracking down ^{210}Pb
- Maintaining the capability to drill 70cm dia. 2500 m deep holes at the South Pole
  - 86 holes, up to 20 holes, in one season demonstrated by IceCube
  - Most of the equipment still at S. Pole but slowly being reassigned
  - Key personnel still available



R&D Crystals
ANAIS Collaboration, Dec. 2012

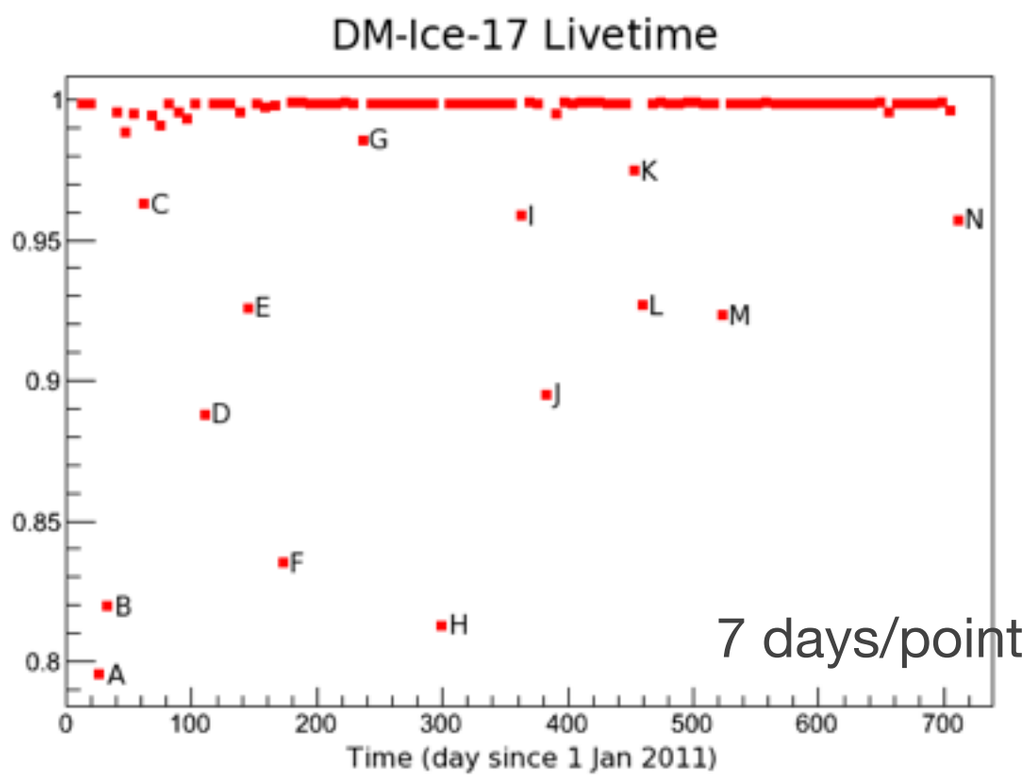


Drill & Deployment Towers
IceCube Drill - 3/4/2013 *Blaise Kuo Tiong*

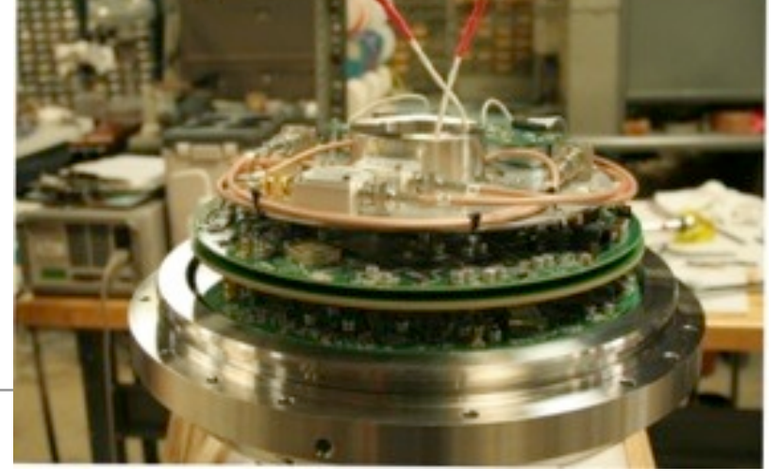
8. Annual Modulation

Detector Uptime: DM-Ice17

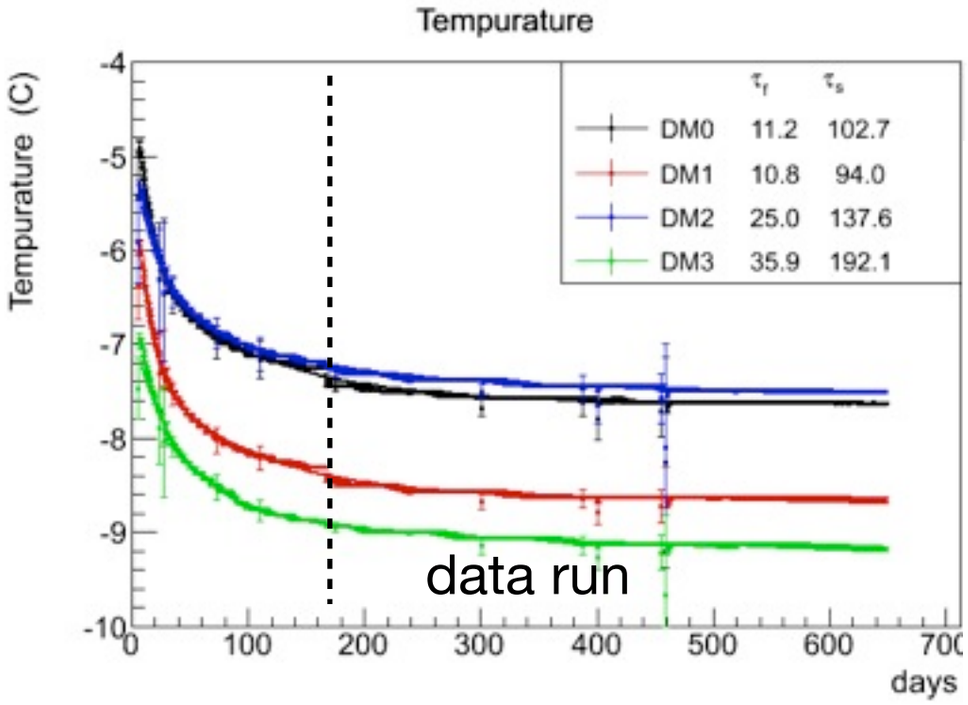
- Commissioning and optimization from Feb - June 2011
- Data run since June 2011
- 99.8% uptime for most weeks with well defined down time for occasional power cycling + pedestal and dark noise runs

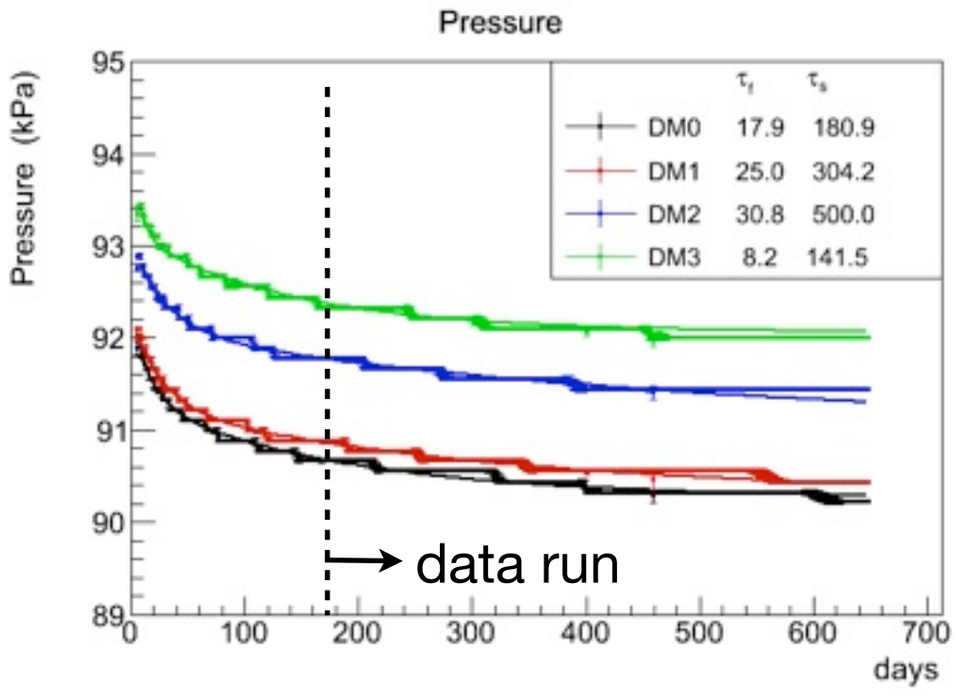


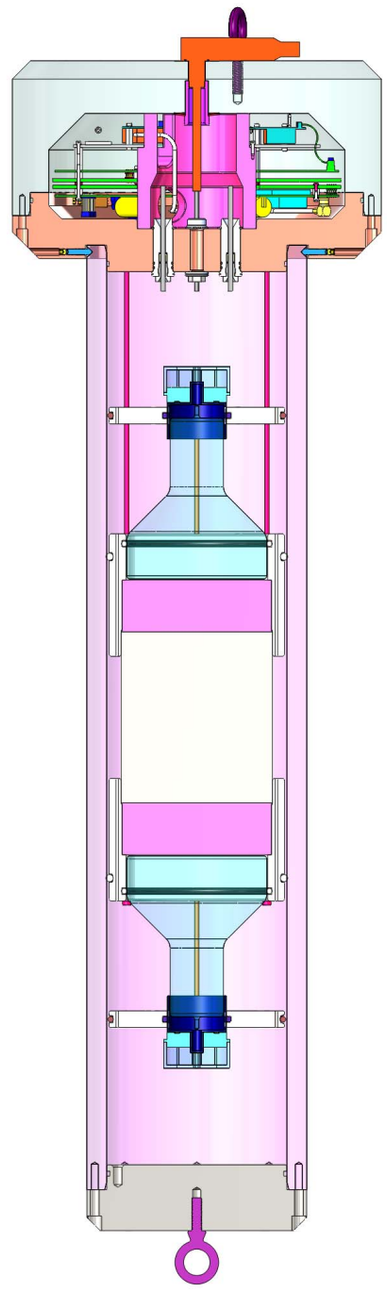
Detector Monitoring: DM-Ice17



- 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.

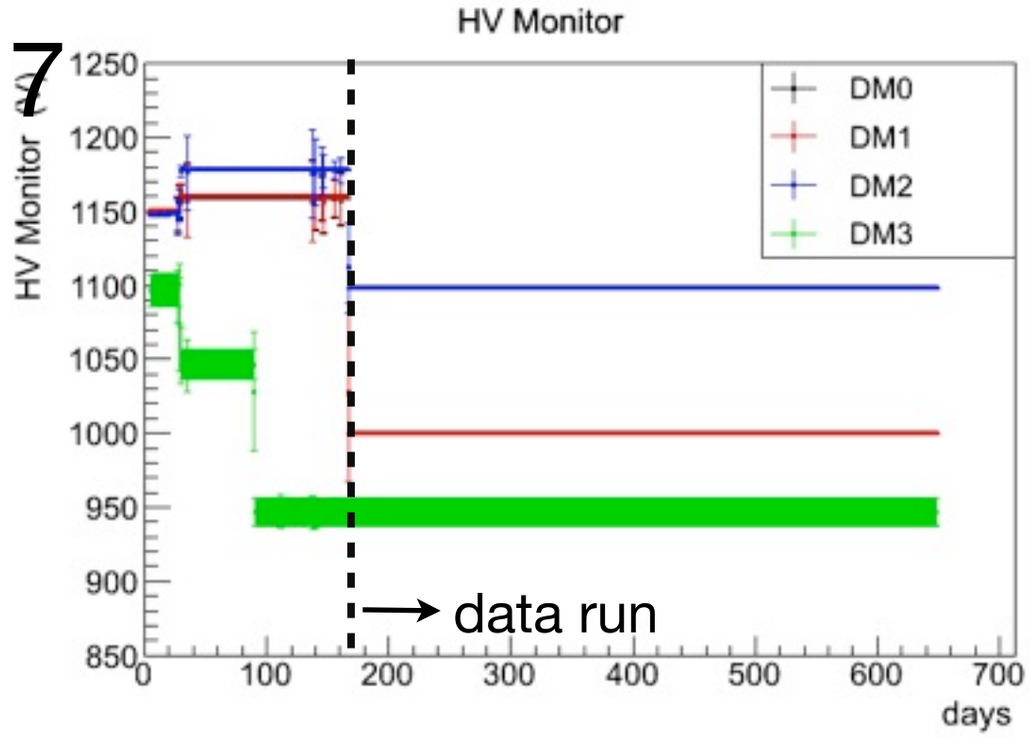


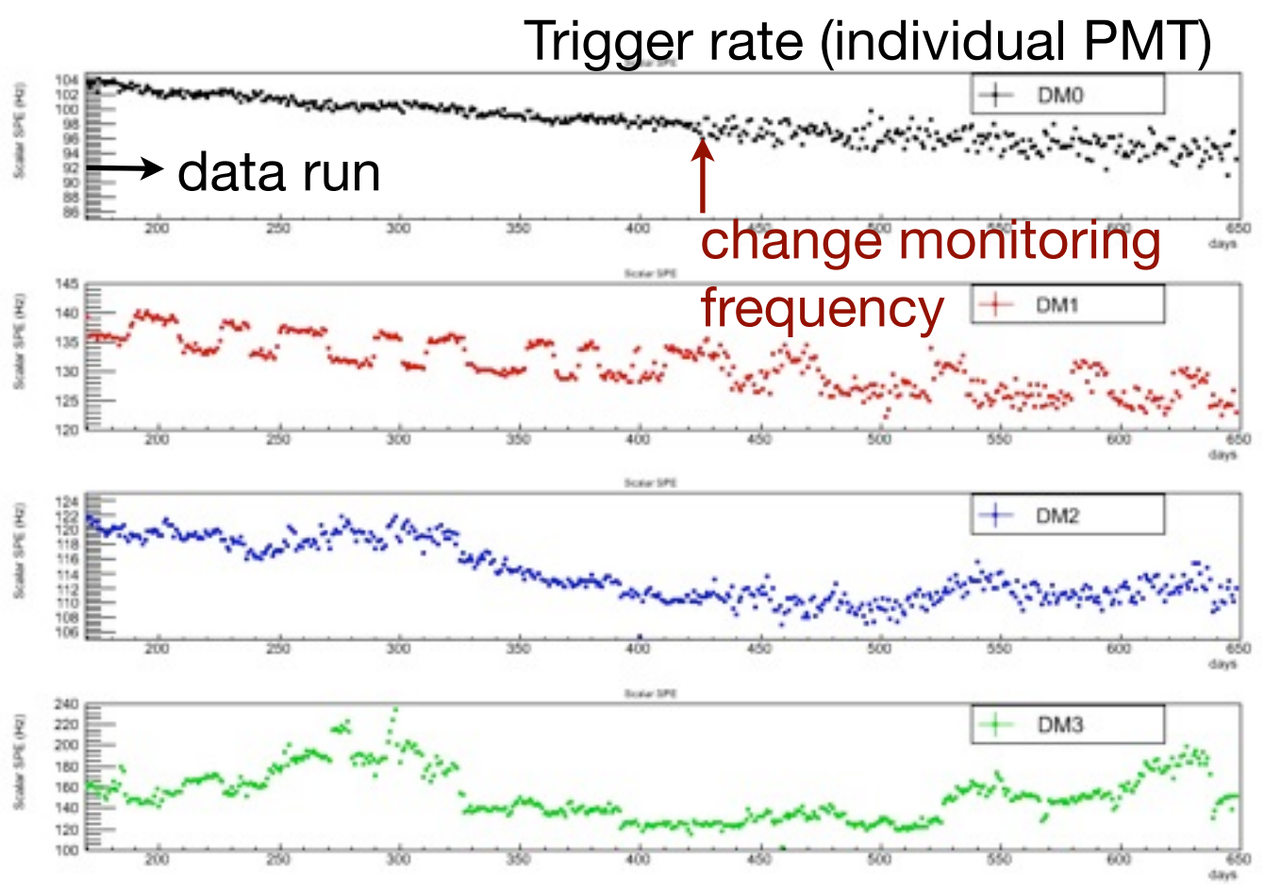




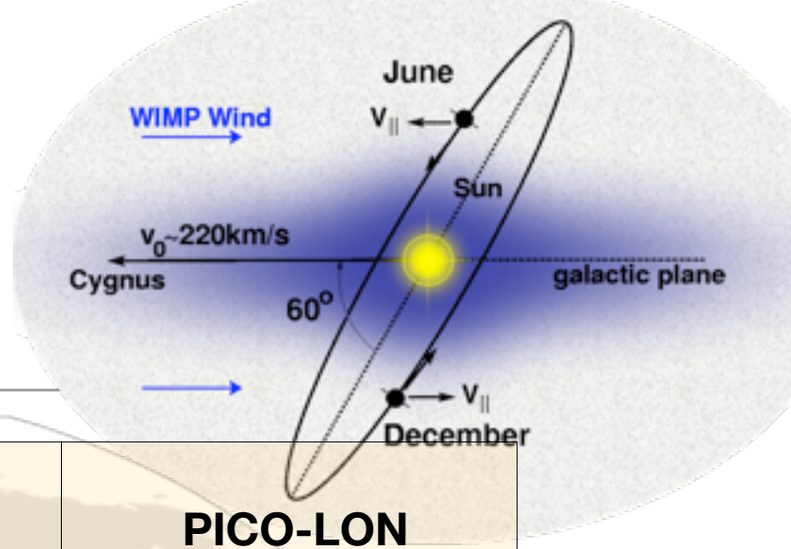
Detector Monitoring: DM-Ice17

- High voltage of each PMT
  - commissioning run until day 167
- Single PMT total trigger rate
  - General decay over time
  - single trigger rate variation seems mostly in the noise
  - coincidence trigger rate at low energy under study





9. Unique Capabilities



Northern Hemisphere	Gran Sasso **DAMA/Libra** 250kg running	Gran Sasso **Princeton-NaI** R&D	Canfranc **ANAIS** 250 kg starting in 2014?	**PICO-LON** **KIMS** etc...
Southern Hemisphere	South Pole **DM-Ice** 17 kg running R&D for 250 kg	**ANDES** Lab (proposed) expected start ~~2018~~ 2017		ice rock under development

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

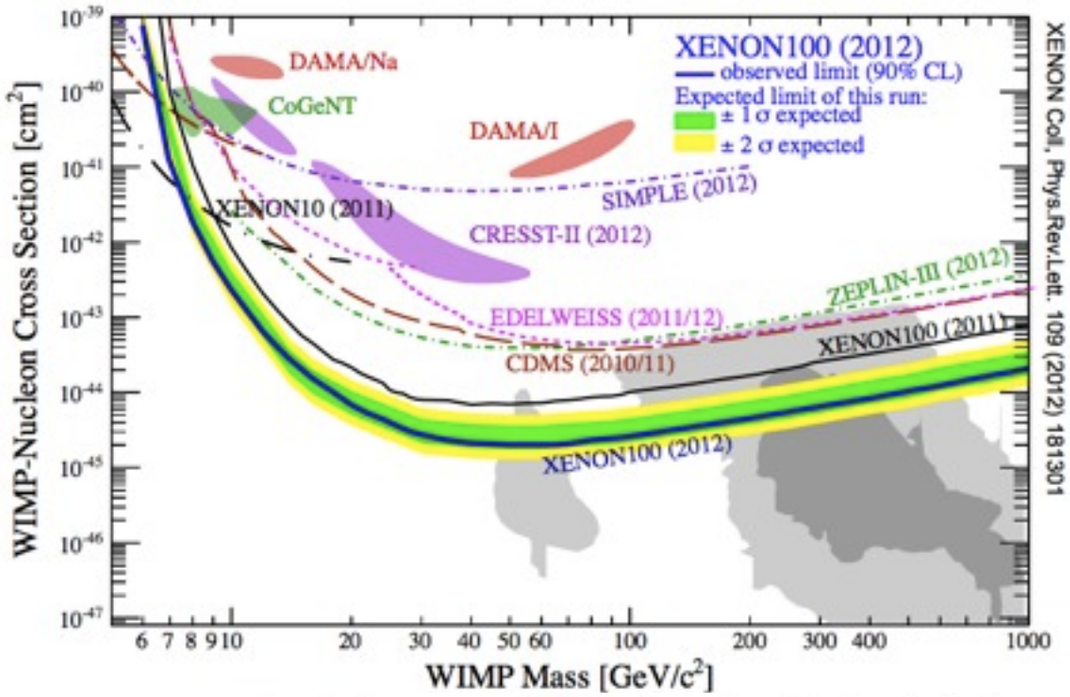
DM-Ice:

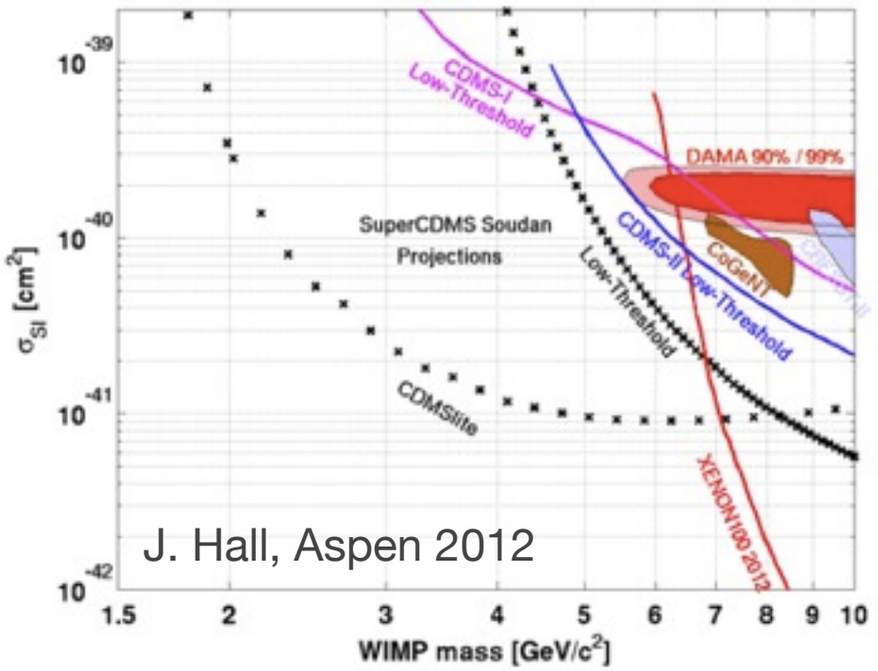
- NaI dark matter search in an entirely different environment
- South Pole offers:
  - Ultra-clean and ultra-stable environment
  - Seasonal variation unambiguously different from dark matter modulation
  - IceCube offers muon monitoring and veto as well as experience
  - NSF-run South Pole Station for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

10. Determining WIMP properties and astrophysical parameters

- DAMA sees annual modulation at 9σ
  - ✳... but is it dark matter?
- 15 years since first claim of observation of modulation
- alternate hypotheses (backgrounds) raised but no definitive answers
- NaI in northern hemisphere will test background hypotheses
- Southern hemisphere experiment test background AND dark matter hypotheses
- As DM experiments grow bigger, there will be many unexplained near-threshold events.

Time to figure out what's going on in DAMA.





Imagine…

a world where we know the origin of DAMA's signal.

DM-Ice Collaboration

University of Wisconsin – Madison
Reina Maruyama, Francis Halzen, Karsten Heeger, Albrecht Karle, Matthew Kauer, Carlos Pobes, Walter Pettus, Zachary Pierpoint, Antonia Hubbard, Bethany Reilly

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