HQE PMT - experiences with first use of 78 PMT in IceCube (Deep Core)

HQE PMT use for IceCube Low energy core

Testing facility and test sequence

Measurements on R7081-02

Measurements on HQE version of otherwise same PMT

Comparisons and conclusions

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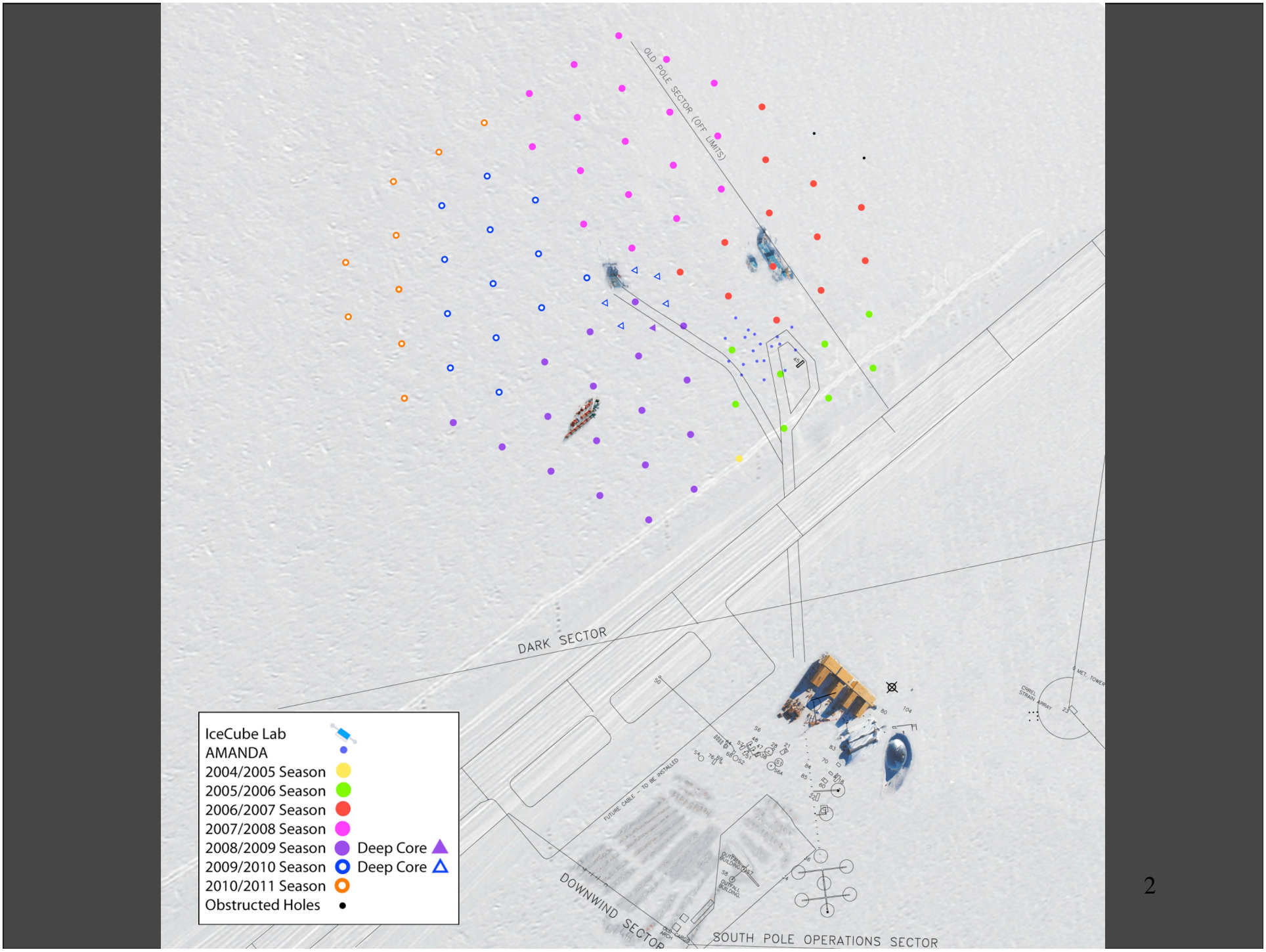
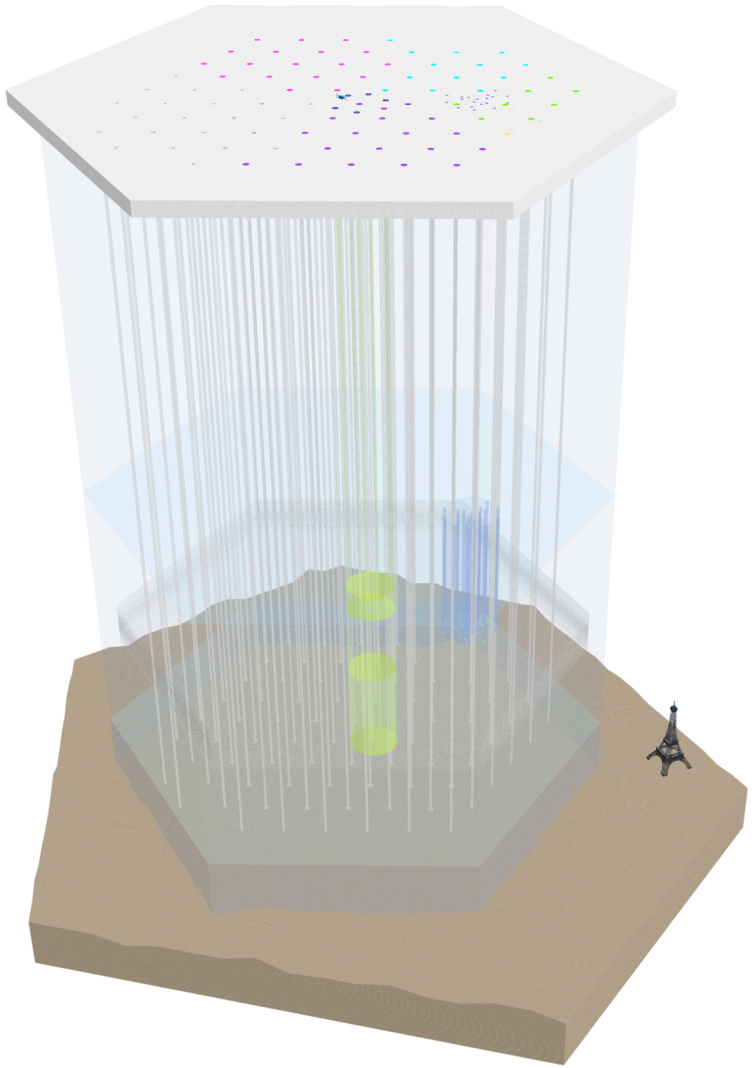
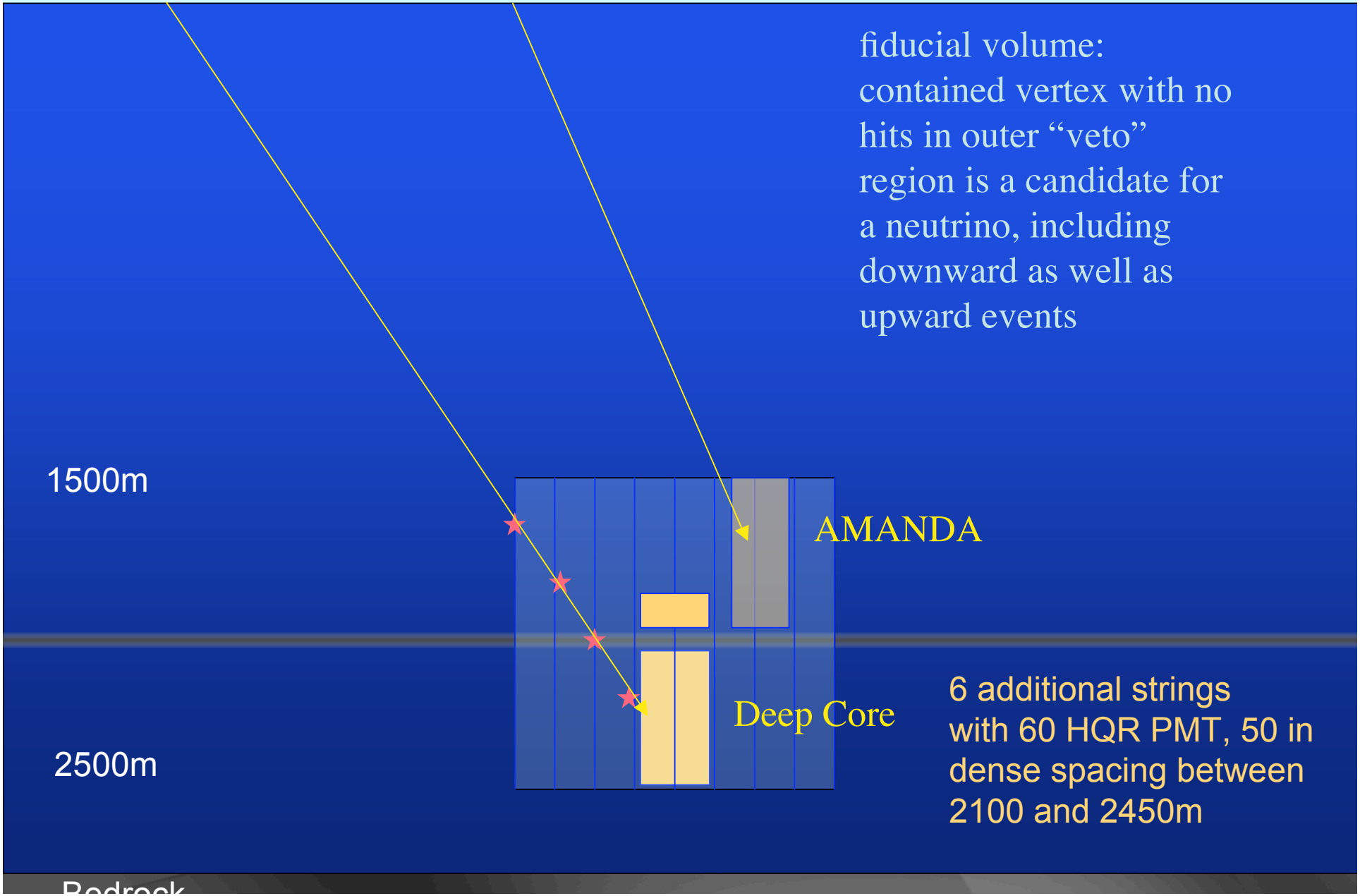

OLD POLE SECTOR (OFF LIMITS)
DARK SECTOR
DOWNWIND SECTOR
SOUTH POLE OPERATIONS SECTOR
FUTURE CABLE - TO BE INSTALLED
IceCube Lab
AMANDA
2004/2005 Season
2005/2006 Season
2006/2007 Season
2007/2008 Season
2008/2009 Season
Deep Core
2009/2010 Season
Deep Core
2010/2011 Season
Obstructed Holes

The IceCube Detector: current state

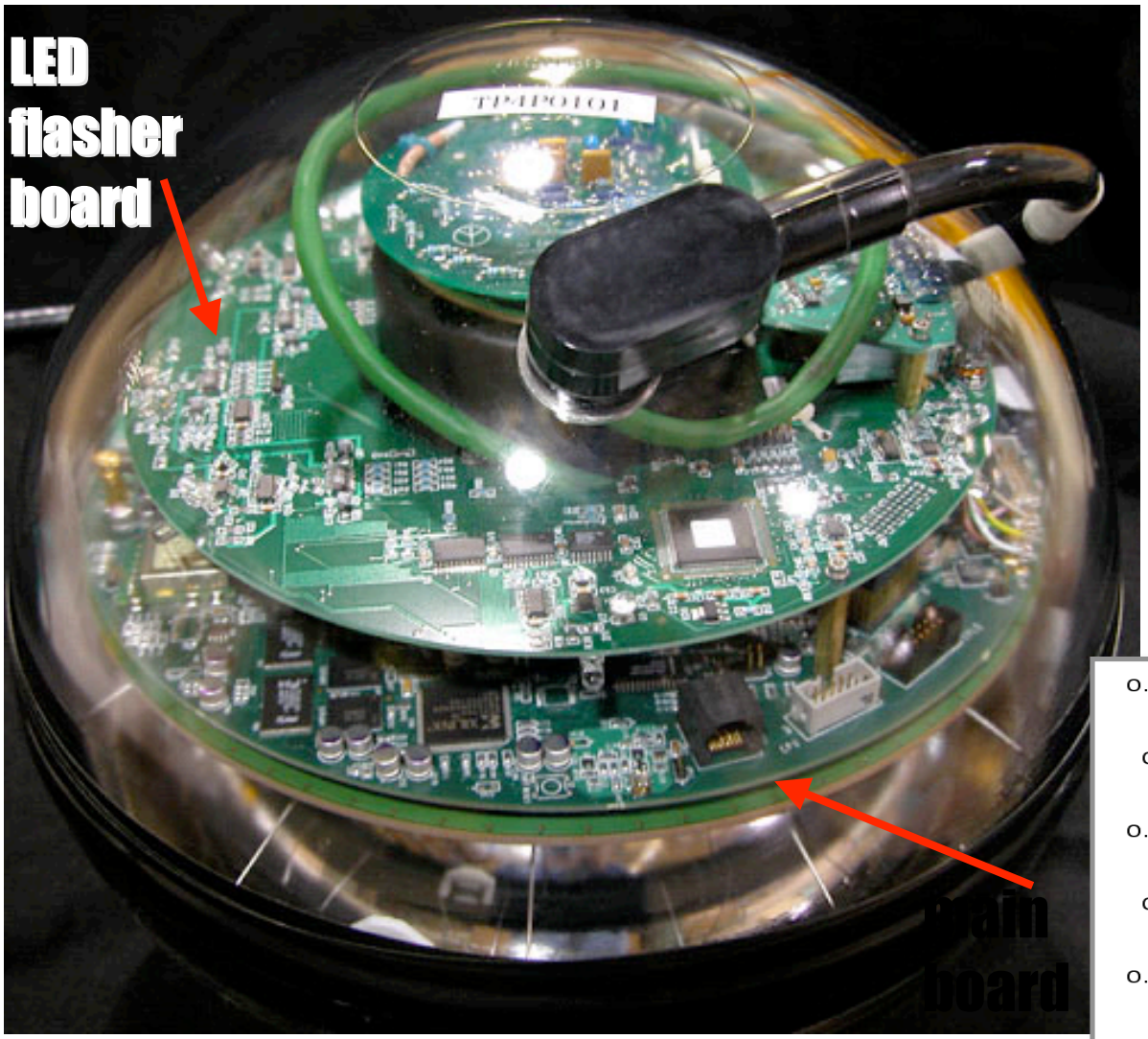
- 19 strings/stations installed during the 2008-2009 austral summer, commissioning ongoing
- Total of 59 strings and 118 IceTop tanks → over two thirds complete!
- Switching from 40 to 59 string operation in April



low energy core for IceCube



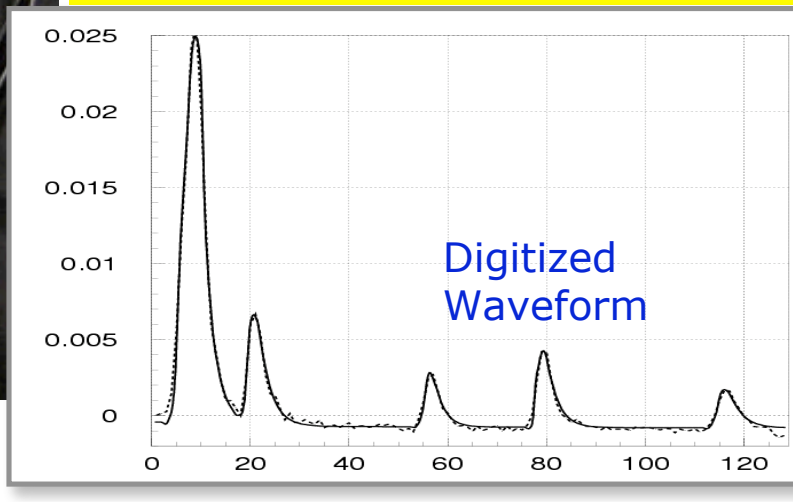
Digital Optical Module (DOM)



PMT: 10 inch Hamamatsu
Power consumption: 3 W
Digitize at 300 MHz for 400 ns with custom chip
40 MHz for 6.4 μs with fast ADC
Dynamic range 500pe/15 nsec

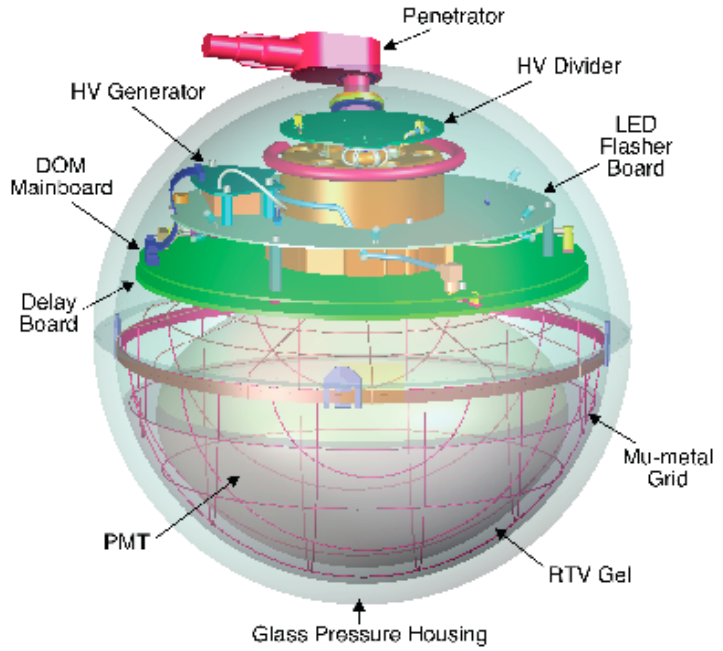
Send all data to surface over copper
2 sensors/twisted pair.
Flasherboard with 12 LEDs
Local HV

Clock stability: $10^{-10} \approx 0.1$ nsec / sec
Synchronized to GPS time every ≈10 sec
Time calibration resolution = 2 nsec



78 high quantum efficiency 10”PMT successfully tested for use in IceCube

- More than 4000 sensors with standard 10” PMT (R7081-02) integrated and tested in IceCube
- 78 high quantum efficiency PMT (10”) tested with IceCube standard production test program.
- Result:
  - Quantum efficiency ~38% higher (405 nm, -40C)
  - No problems found
  - Low temperature (-40C) noise behavior scales with quantum efficiency as expected.
- Deployed all modules in the ice this past season



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Main Production Room
Operations Include:
•GEL Prep & Pour
•Penetrator Install
•Board Stack install
•Penetrator Soldering
•Sealing & Pre-Test

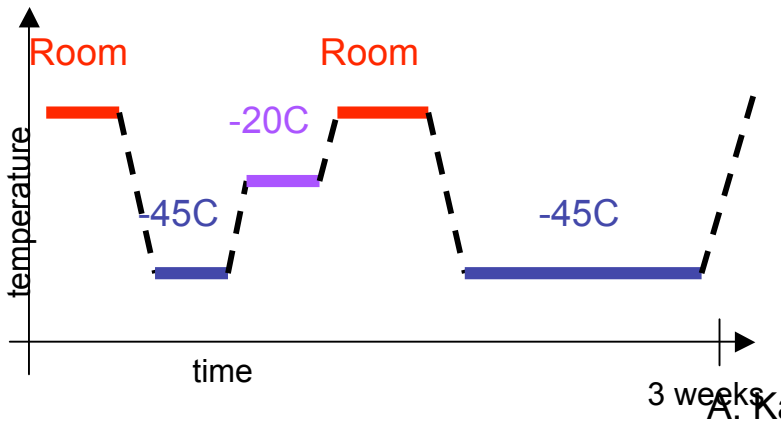

IceCube Warehouse
•Material Storage
•Packing

Dark Freezer modules

PMTs were run through standard final acceptance tests for IceCube

- Mass production tests
- All sensors are tested for 3 weeks for various parameters

Testing Temperature Profile



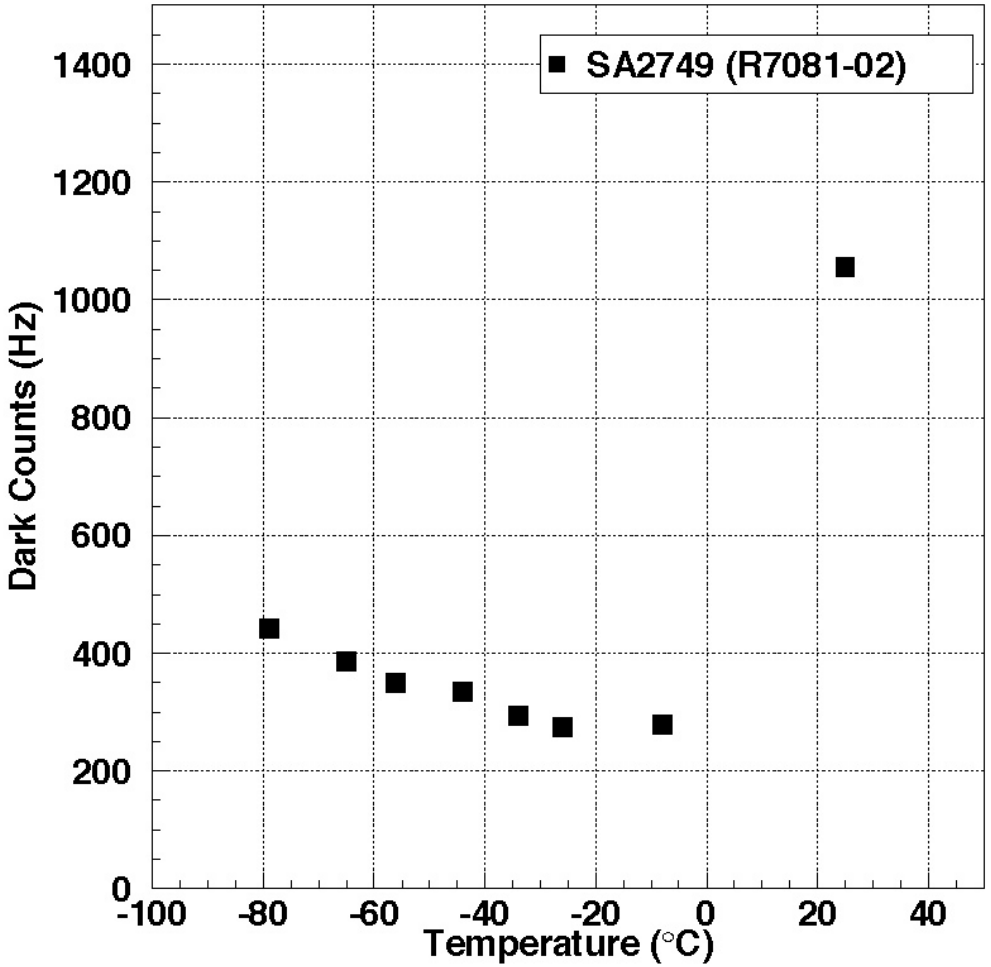
Testing Setup

Hamamatsu R7081-02 (standard IceCube, conventional cathode)

- Diameter: 10’’ (hemispherical)
- Cathode: Standard Bialkali
- Quantum efficiency: ~25% at 420 nm
- Dynodes: 10 (selected over 12 stage and another version)
- Gain: 10^7

Noise rate versus temperature

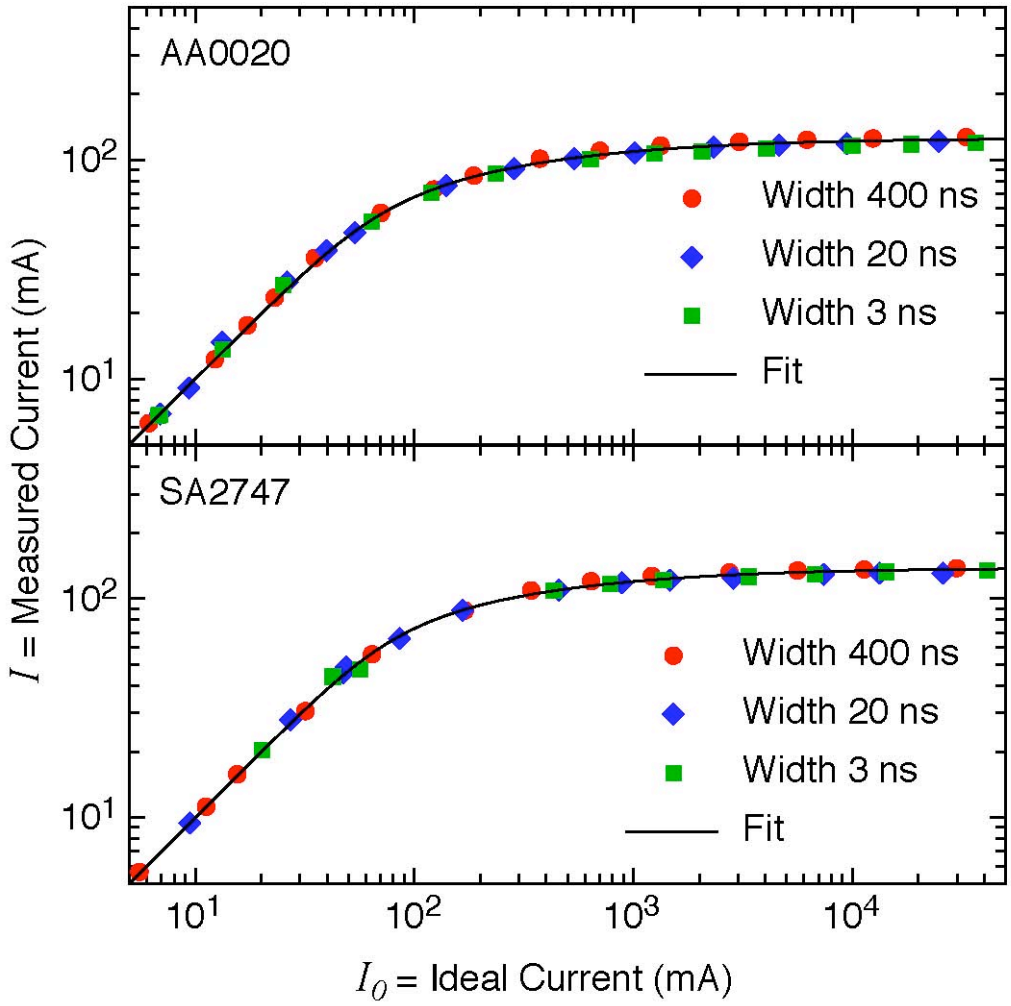
- Minimum noise level: ~300 Hz at ~-10C



PMT saturation curve

a) Saturation at ~100 mA anode current.

b) Saturation behavior is the same regardless of the width of light pulse



Response to diode laser pulses

a) Main pulse
b) Secondary peak du unusual electron trajectories
c) Pre-pulse (from firs dynaode, are belo threshold. Gain rati accordiing to first d gain)

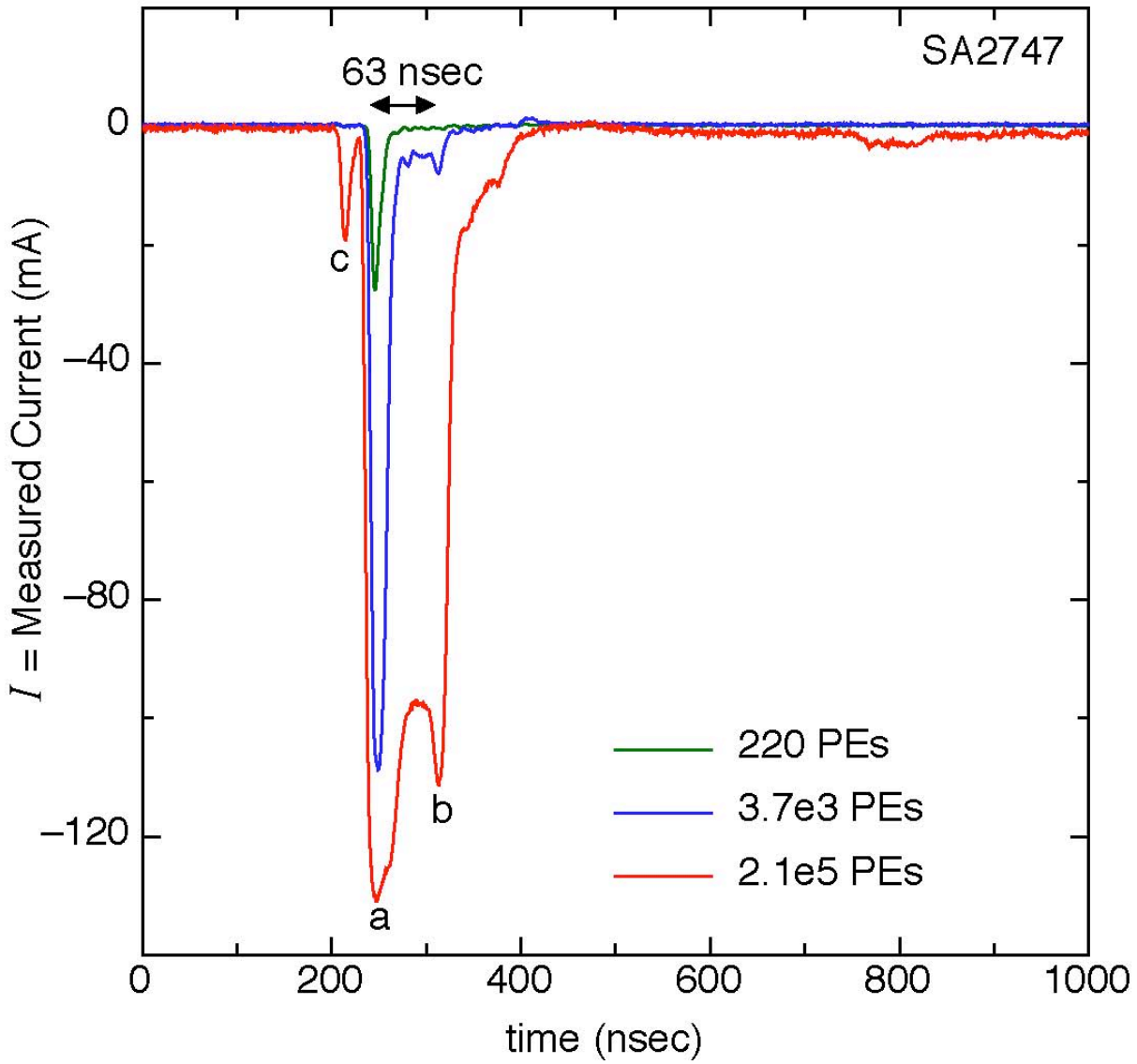
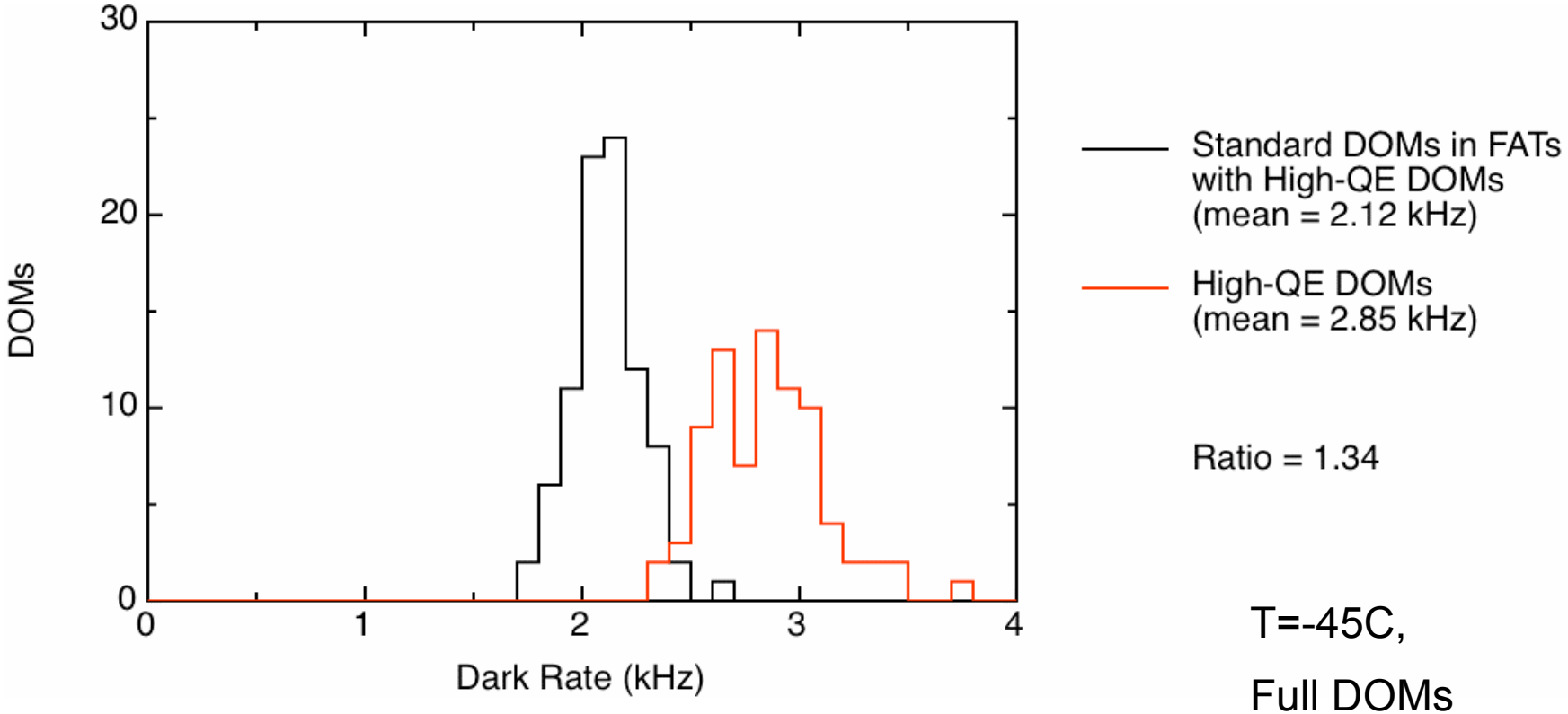


Fig. 16. Response of PMT to 3 ns (FWHM) light pulses with progressively higher-intensity: (a) main peak; (b) secondary peak due to unusual electron trajectories; (c) pre-pulse.

Noise rates of sensors

conventional vs high QE



T=-45C,

Full DOMs (w.Pressure housing)

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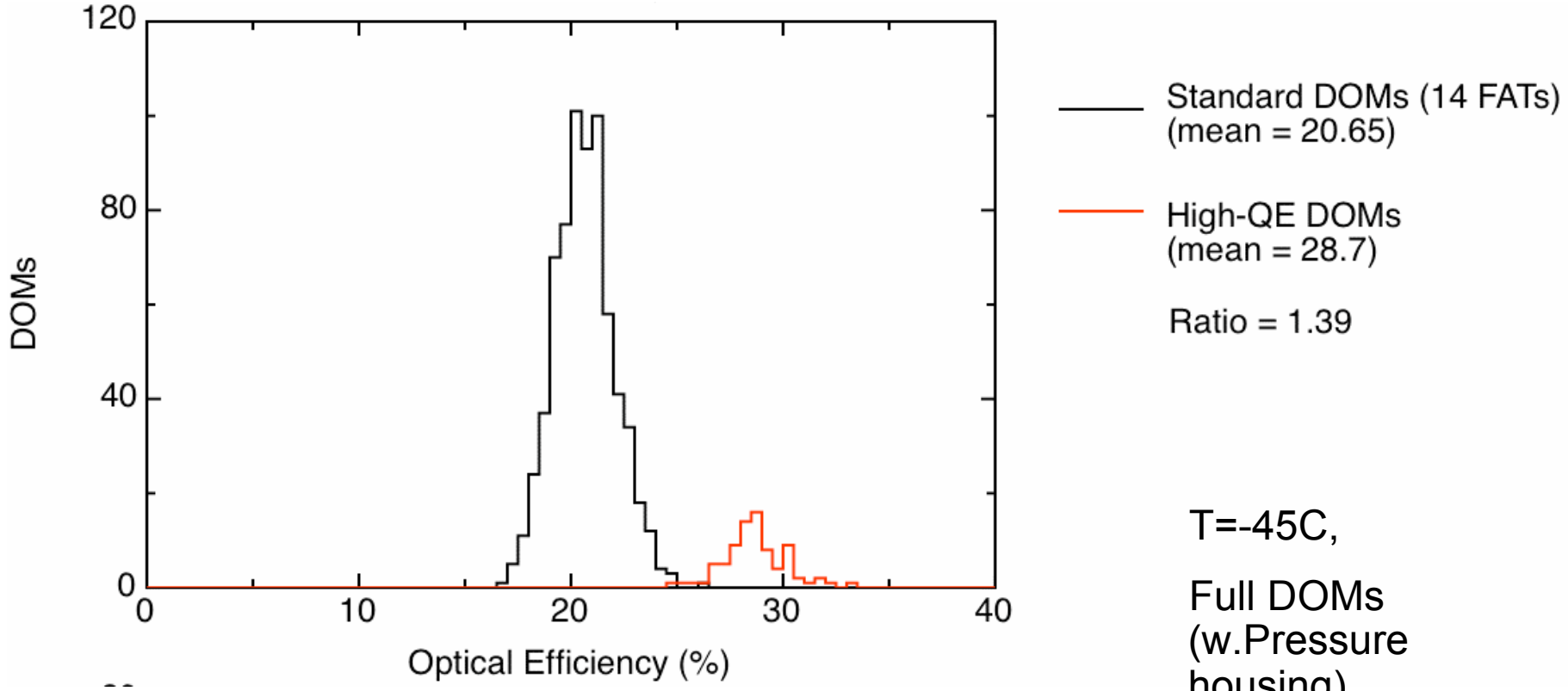
Relative optical efficiency of sensors
(conventional vs high QE)



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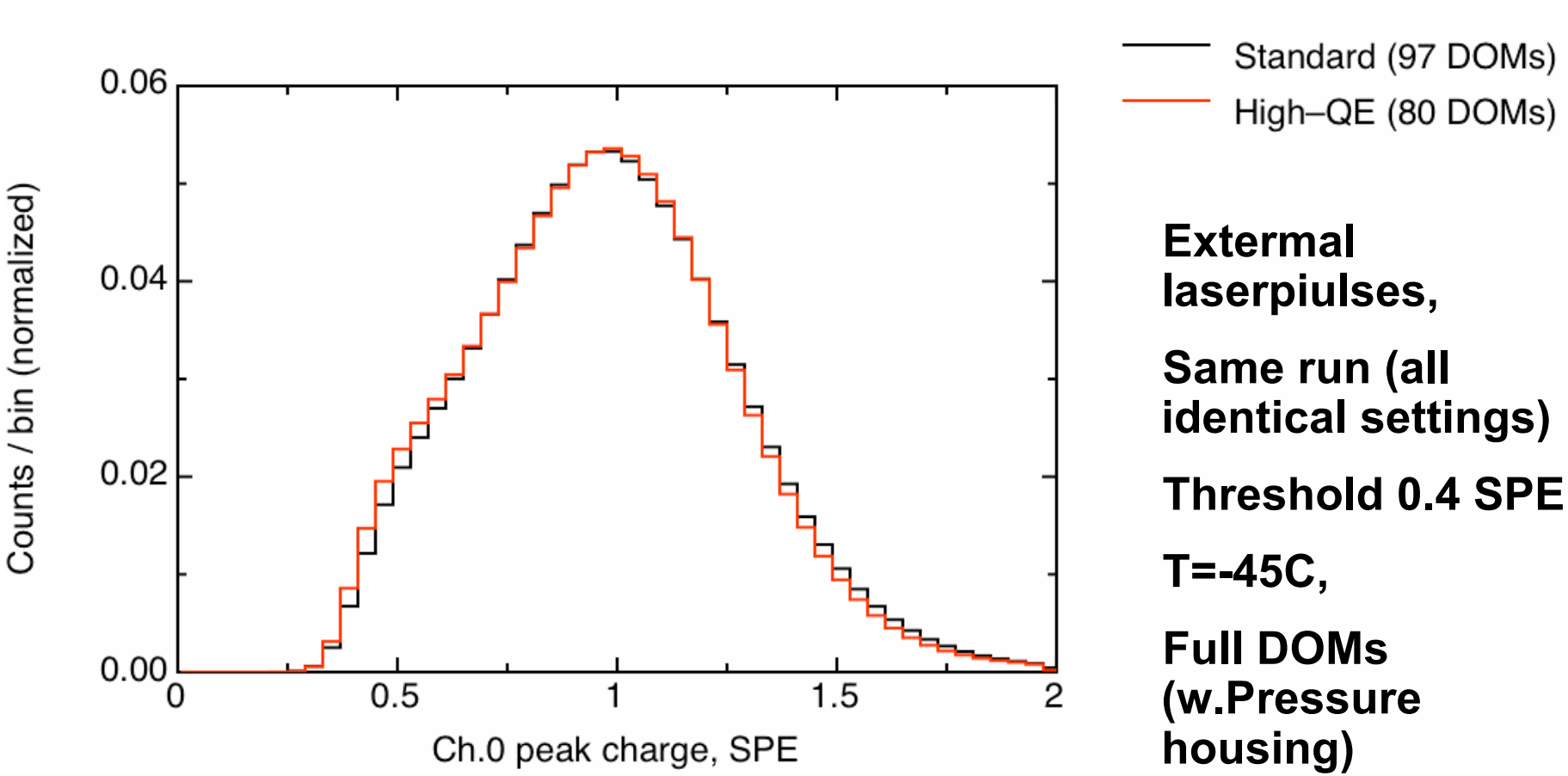

Extermal laserpiulses,

Same run (all identical settings)

Threshold 0.4 SPE

T=-45C,

Full DOMs (w.Pressure housing)

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Noise rates of HQE PMT sensors in ice

- Preliminary data are on noise rates in ice look good.
- Noise rate should scale primarily with quantum efficiency compared to standard sensors (if no additional thermal or other noise emission present).
- Data suggest that is the case.
- Noise rate of sensors (including secondary pulses from glass scintillation):
  - Sensor with standard PMT: 350 Hz
  - Sensor with HQE PMT: ~ 470 Hz (very first data, rates are still dropping slowly, not stable yet)
  - Ratio: ~1.4

- Need to wait until cooling down completed and more detailed analysis is done.

HQE PMT summary

- 78 HQE PMT tested, almost as many deployed in ice.
- Most data taken at low temperature (-45C)
- All data look very good and within expectations.
- Sensitivity about 1.35 higher than standard PMT
- Appears reasonable to use HQE photocathode for preliminary planning assumption of large water Ch detector
- Test and lab facilities at PSL could be made available for DUSEL collaboration, for test and assembly purposes if useful.