R&D for the Next Generation IceCube: IceCube-Gen2

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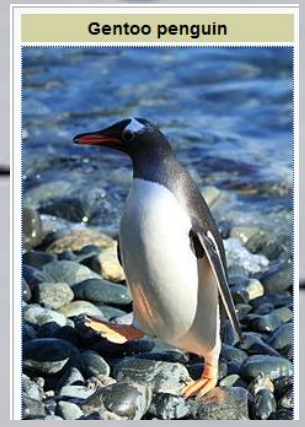
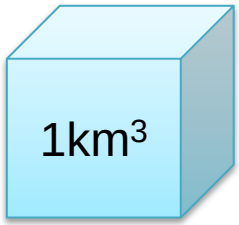


Neutrino Frontier Workshop 2014

Outline

- What we've leant from IceCube
- What we want to achieve in the next decades in neutrino astrophysics
- IceCube-Gen2
- Initial optical sensor R&D for IceCube-Gen2
- Outlook

What we learnt from IceCube

The conceptual 

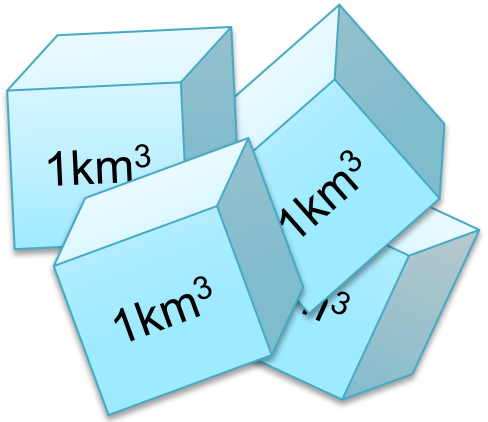
neutrino detector has shown:

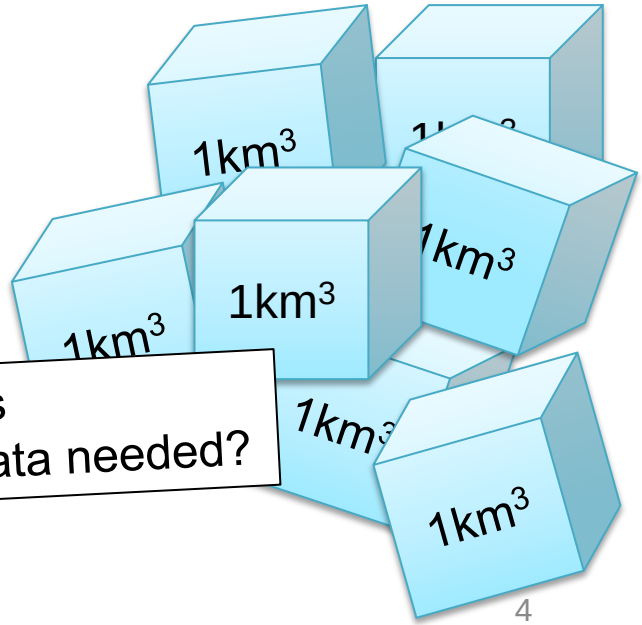
- Working well at South Pole
- High level of astrophysical neutrino flux
  - ✓ cosmic ray sources are efficient neutrino sources
- Neutrinos above 1 PeV from Southern sky (3events/3years)
- Spectral indices and shape, $\phi \propto E^{-2.3}$ at high energies
  - some hints of softening with reducing energy threshold, or another component
  - wider energy range measured with cascades/starting events (30TeV-2PeV)
  - narrower energy range with up through going muon (500TeV- 1.2PeV)
  - Flavors consistent with $\nu_e : \nu_\mu : \nu_\tau$ =1:1:1 or any model

What to be achieved in the next decades in neutrino astrophysics

(at minimum)

- Discoveries
  - neutrino point sources
  - PeV tau neutrinos
  - $\bar{\nu}_e e^- \rightarrow W^-$ Glashow resonance events
  - GZK neutrinos (E>10PeV)
- Precision measurements
  - cosmic neutrino spectra
  - flavors
  - anisotropy
- And more…





how many more times
an IceCube year of data needed?

Data requirements for the target

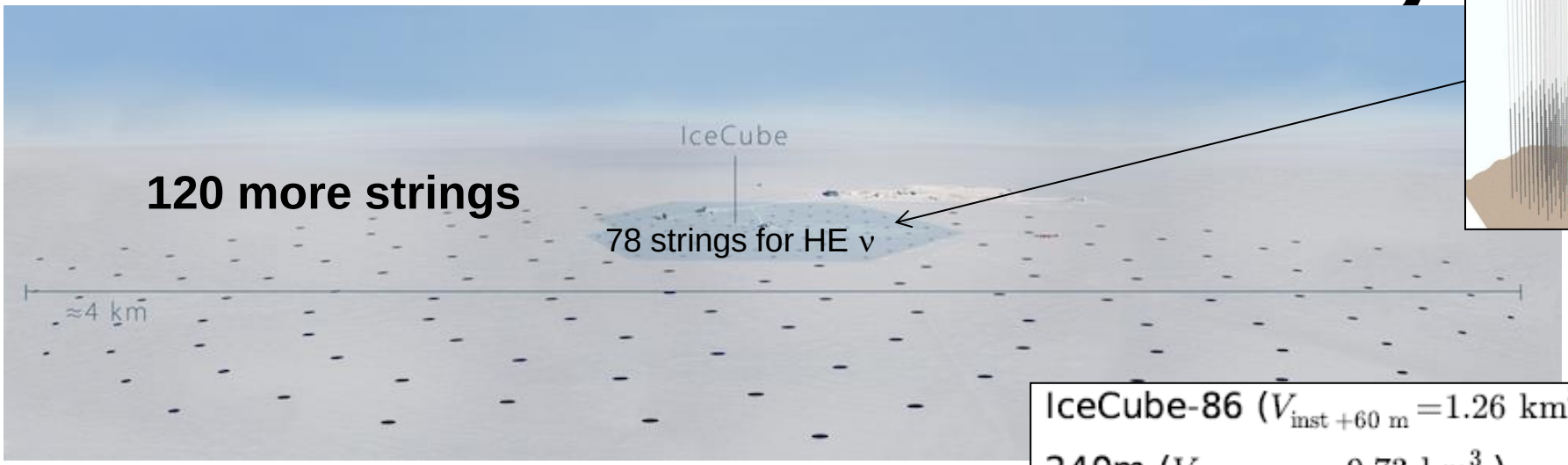
In particular for point sources

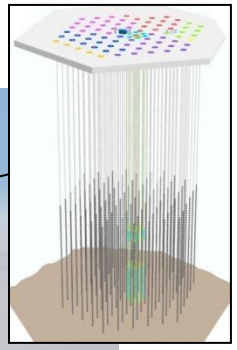
1. More statistics. Assuming neutrinos are from ordinary, common objects in the Universe, ~1000 cosmic neutrino events with IceCube conservatively estimated to be needed
2. Better angular resolution (Needs less number of signal events for PS search)
3. More effective muon veto detector to reduce background

Note that current rates are,
up throughgoing muon ~10 signal events/year (area)
cascades ~30 events/year (volume)

➡ **target signal rates >200/year, 5~7 x IceCube**

IceCube-Gen2 Geometry

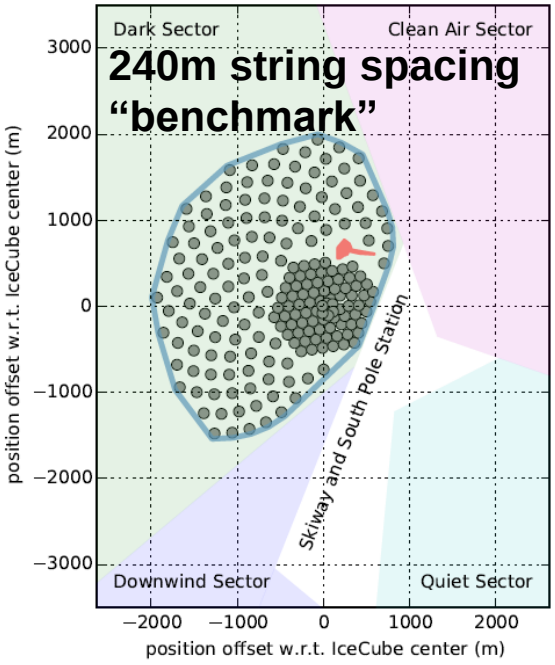


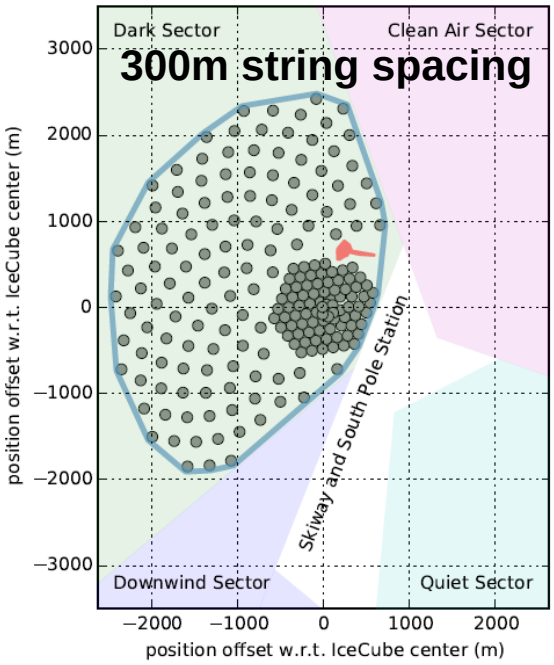


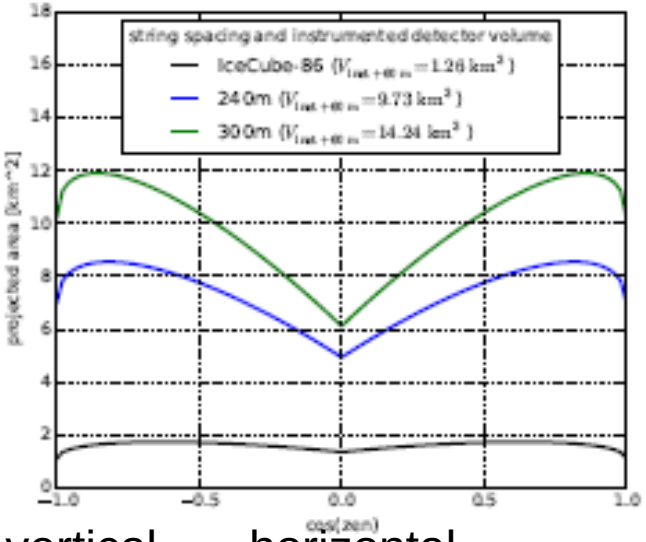
IceCube-86 ($V_{\text{inst }+60\text{ m}} = 1.26\ \text{km}^3$)

240m ($V_{\text{inst }+60\text{ m}} = 9.73\ \text{km}^3$)

300m ($V_{\text{inst }+60\text{ m}} = 14.24\ \text{km}^3$)







vertical horizontal

New Optical Modules design proposal from Chiba for IceCube-Gen2

8” SBA PMT R5912-100

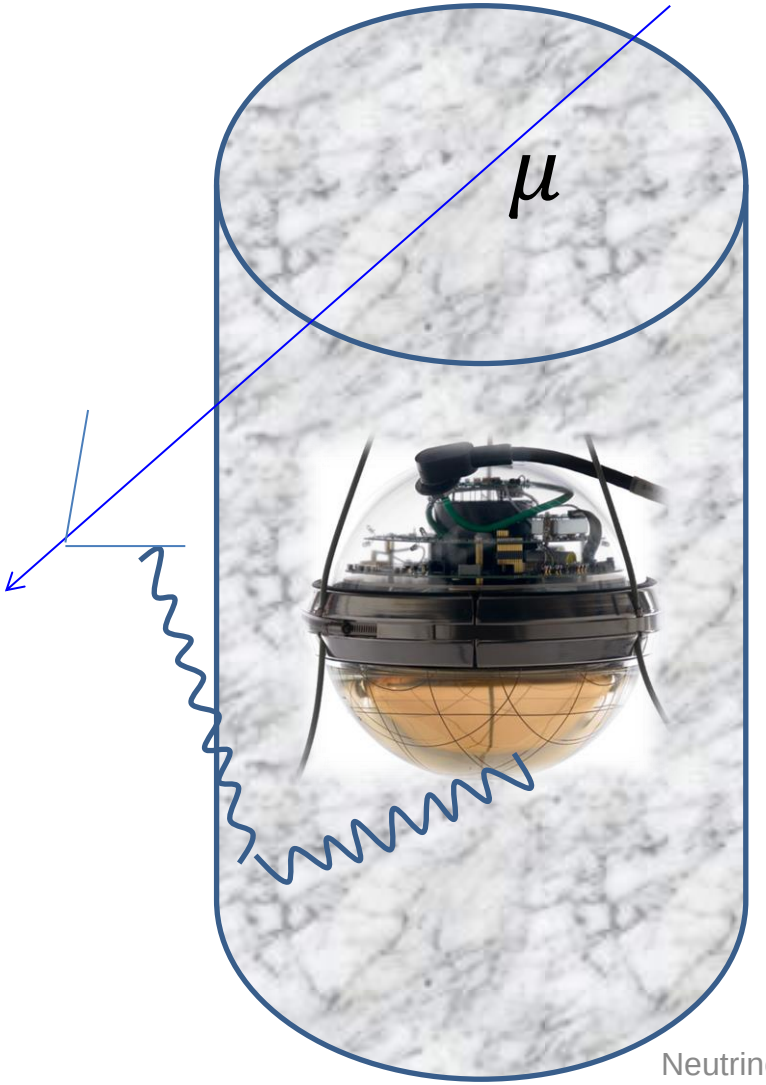
to observe

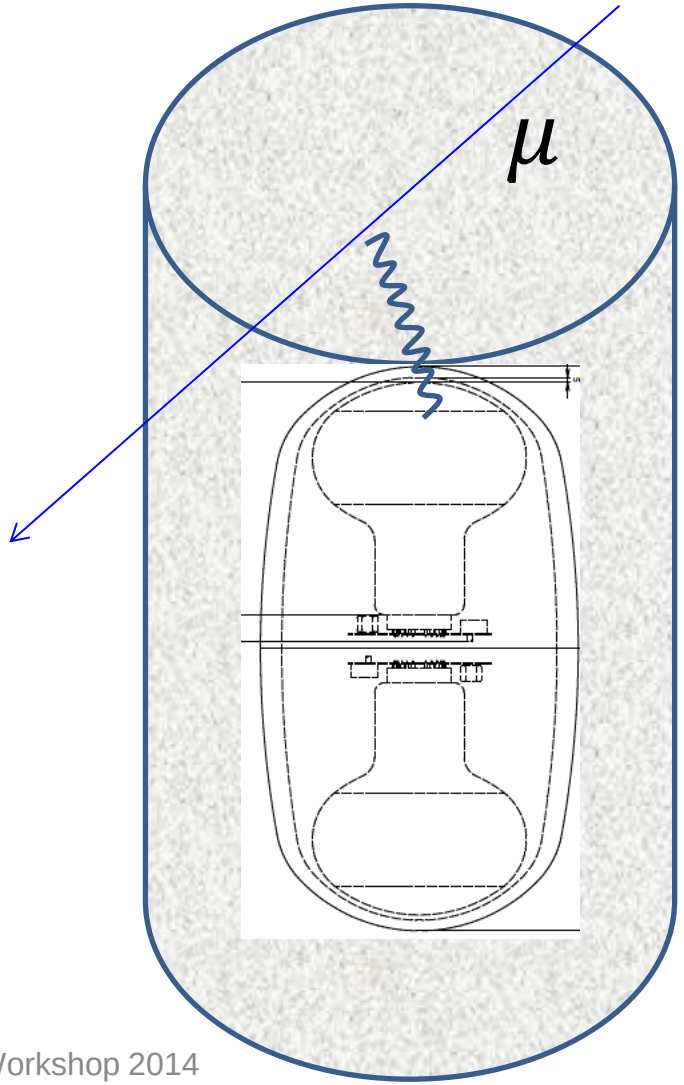
- **More signal events**
- **Better angular resolution**
- **Better muon veto**

- Realize higher photon detection efficiency
- Up/down symmetric PMT configuration

Up and down symmetry

There is a planned upgrade for drill which will make a cleaner ice around the optical module
Down-going muon identification is crucial to reduce the background

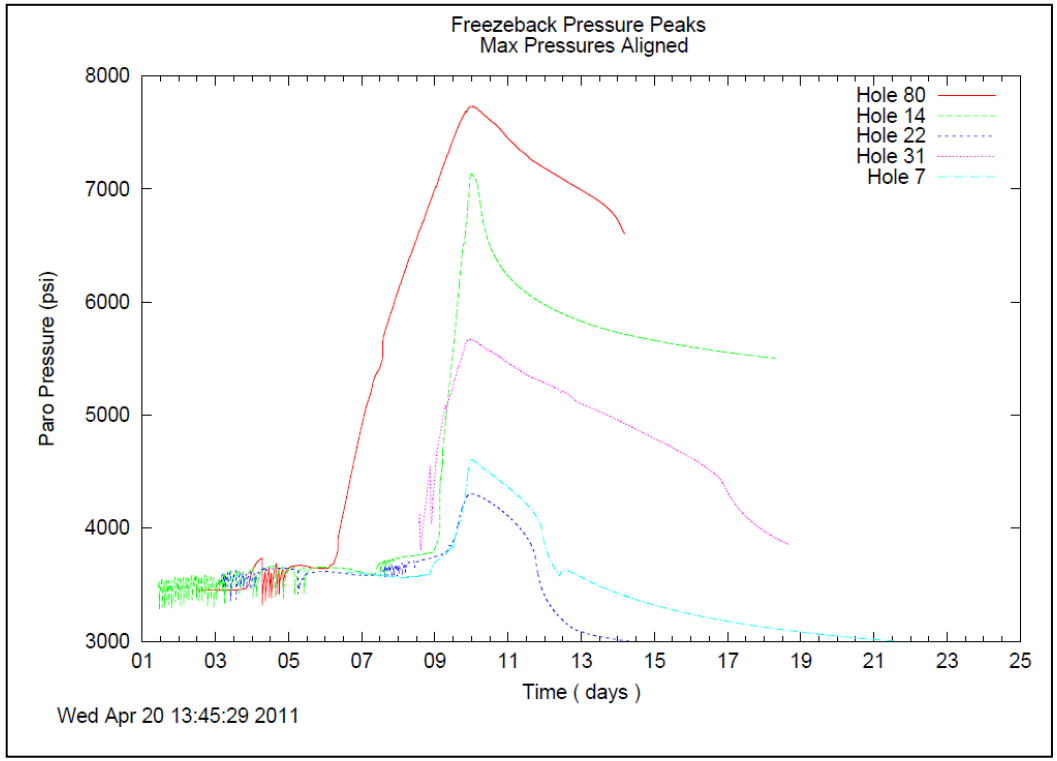




Pressure requirements for housing

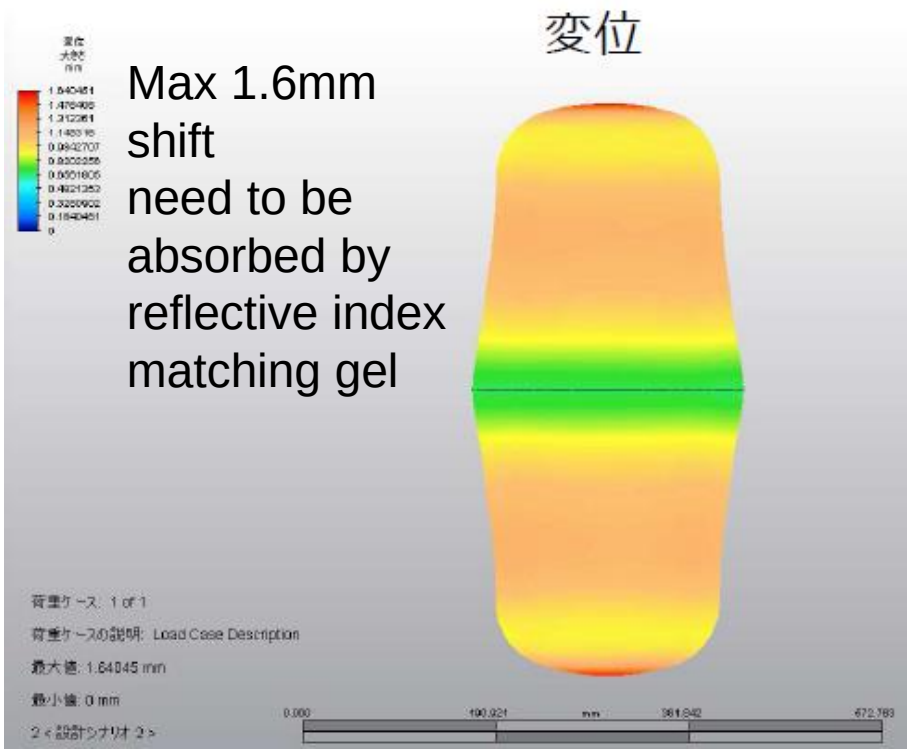
Measured pressures during the deployments: still keep the same conservative requirements for IceCube Glass Sphere

- Overpressure (absolute) 10000 psi (650 bar) for 7 days (During freeze-in process)
- Maximum Operating absolute pressure 3650 psi (250 bar)



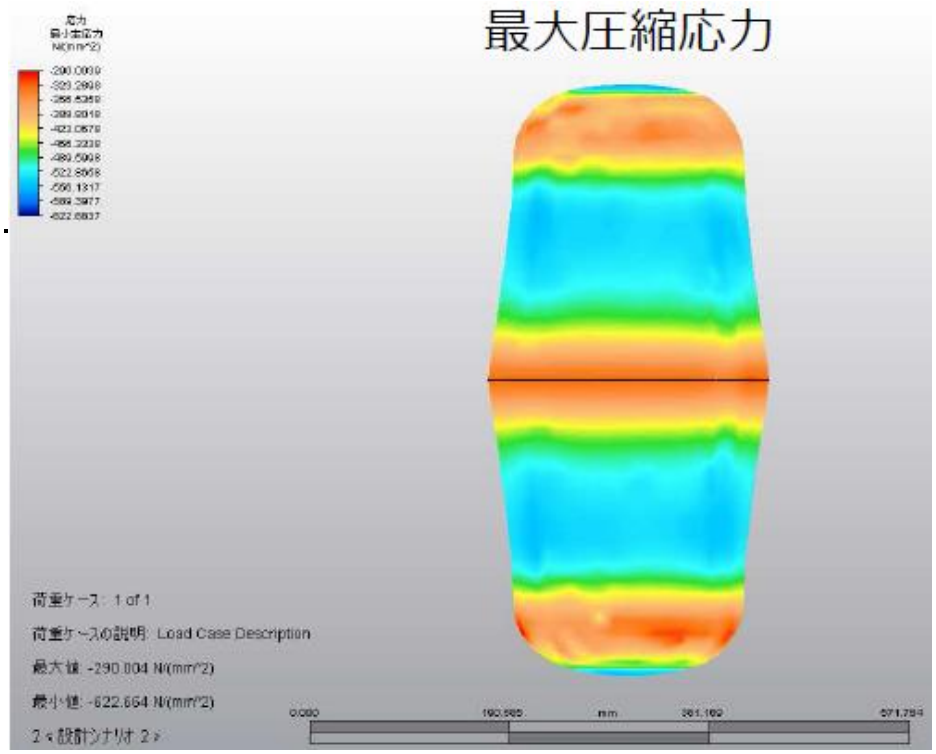
Simulations with 10000 psi

buckling stress

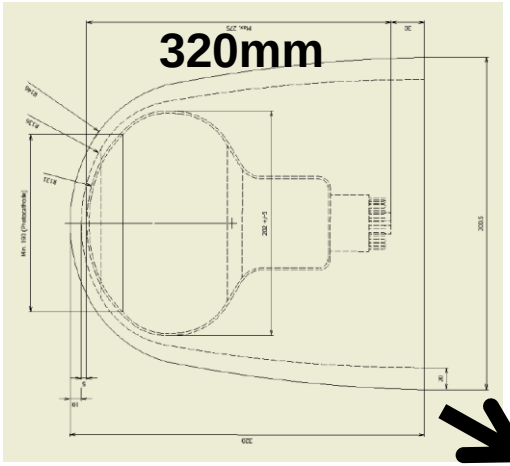


Max 1.6mm shift need to be absorbed by reflective index matching gel

compressive stress



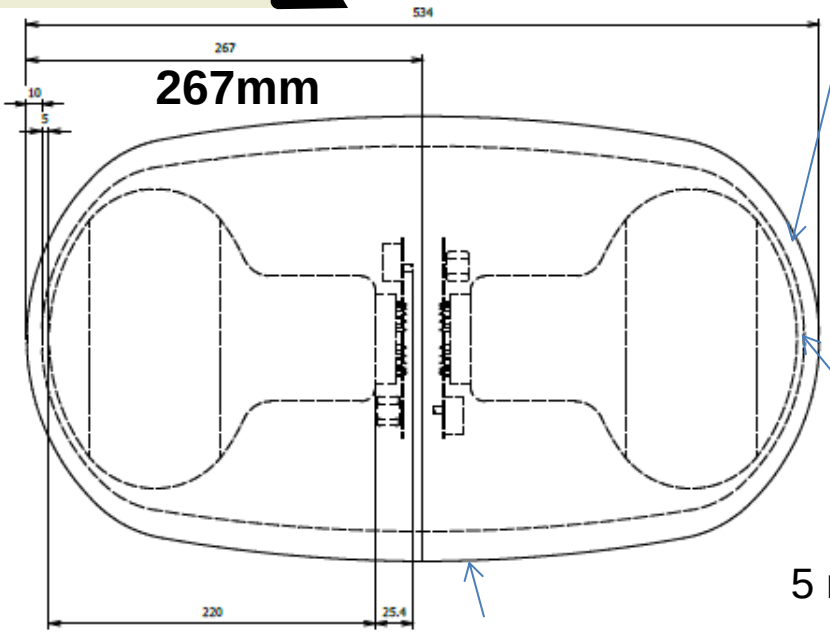
Pressure-resistant glass sphere design

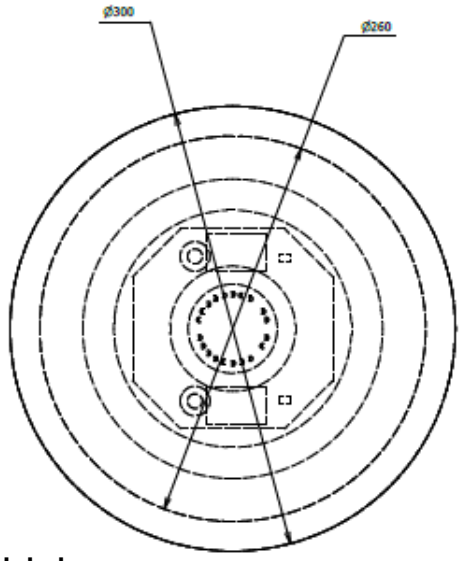


-53mm

- 密度2.35で約9500g
- 出来れば8000gが望ましい(by ガラス屋さん)

10 mm thickness





5 mm gel thickness

20 mm thickness

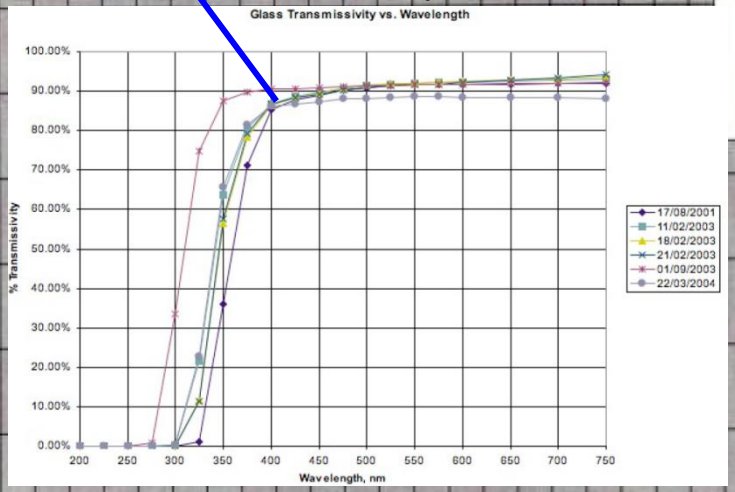
Glass transmittance

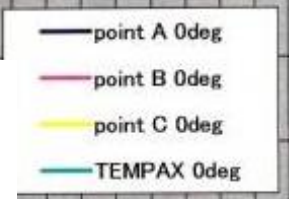
- Significant improvements in <400nm,
- More than a factor of 2 improvements in < 300nm

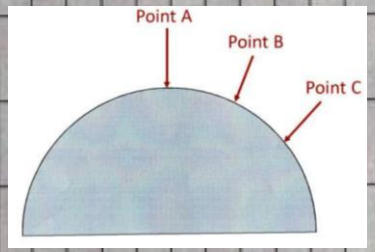
new glass 9mm (design thickness 10mm)

Standard IceCube Glass

from IceCube Internal Report:201102011







transmittance(%)

wavelength(nm)

Gel transmittance

- Overall Improvements over wide range
- Better performance in <300nm

new gel 3.5mm (design thickness: 5.0mm)

Standard IceCube Gel

IceCube Internal Report:201102011

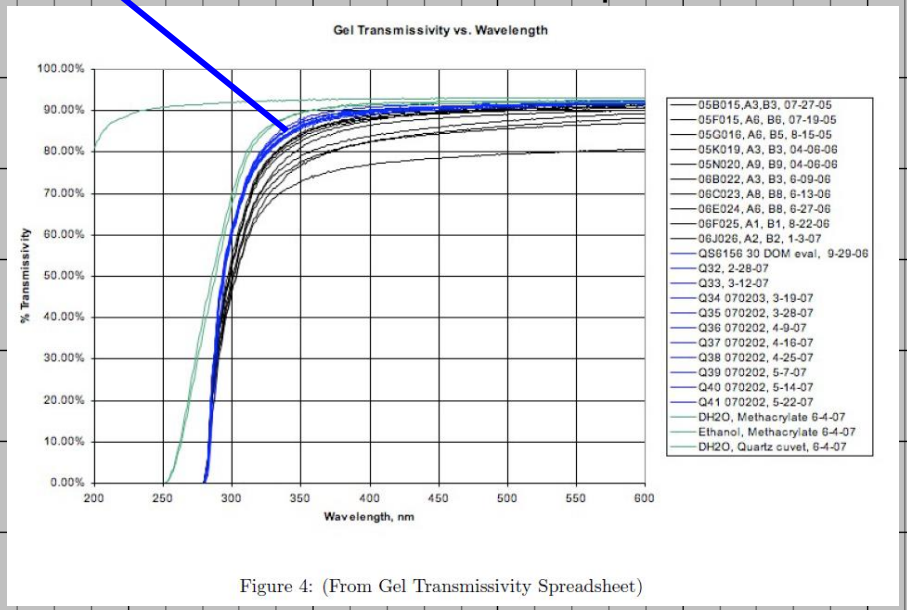
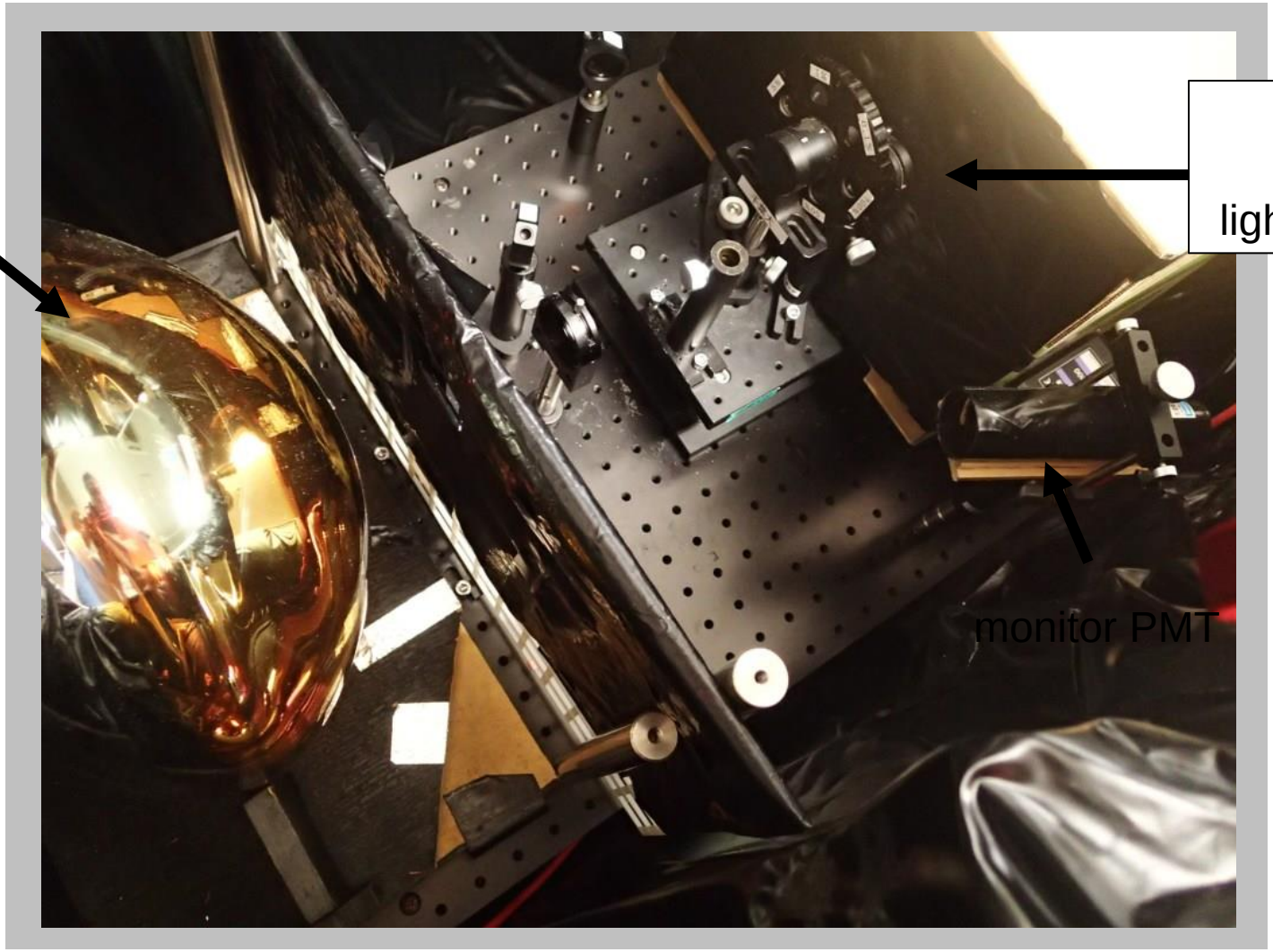


Figure 4: (From Gel Transmissivity Spreadsheet)

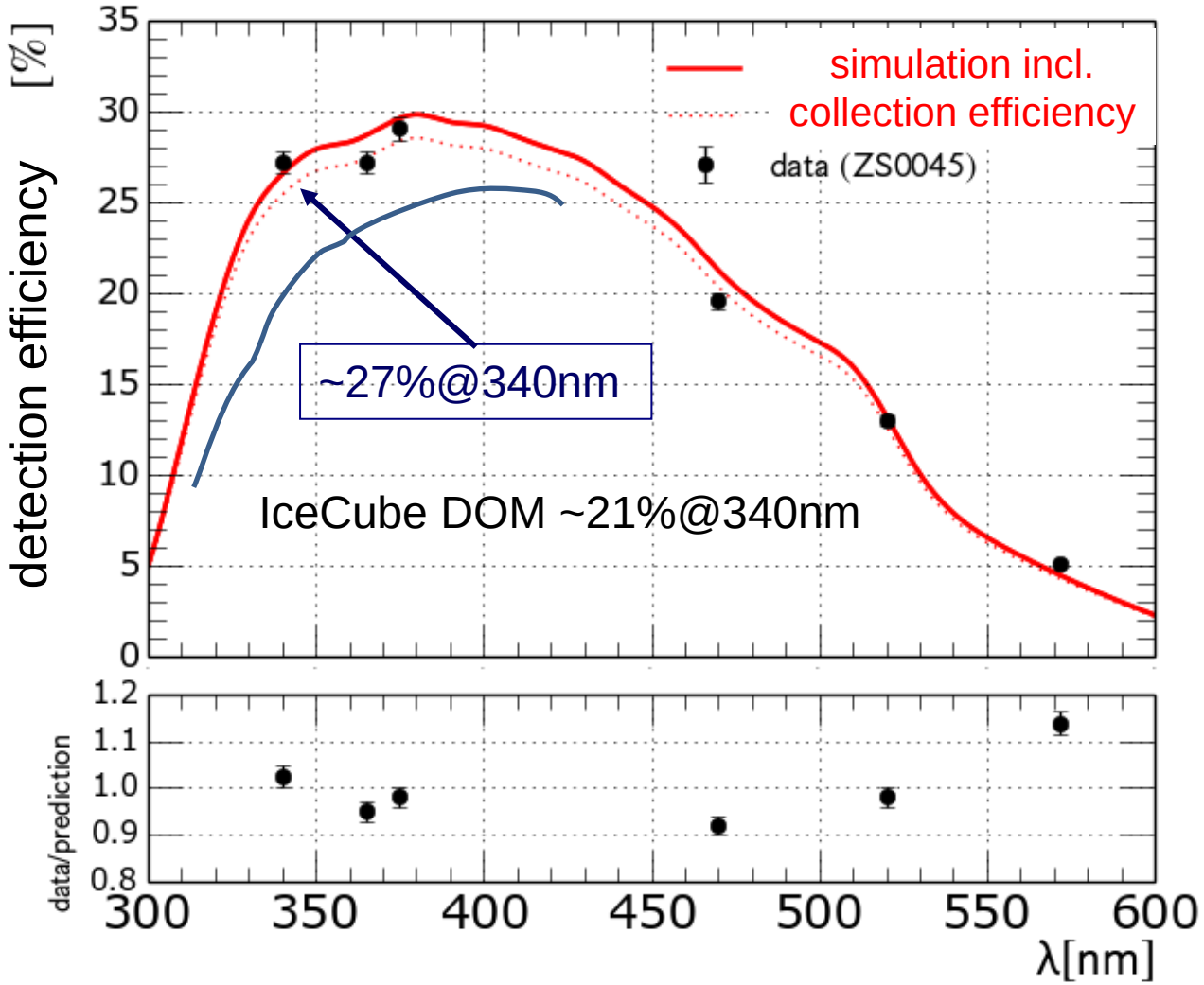
R5912-100 PMT measurement 1

Quantum + Collection efficiency measurement in a freezer box (~ -40C)



PMT measurement result 1

photo detection efficiency = QE x CE



PMT measurement 2

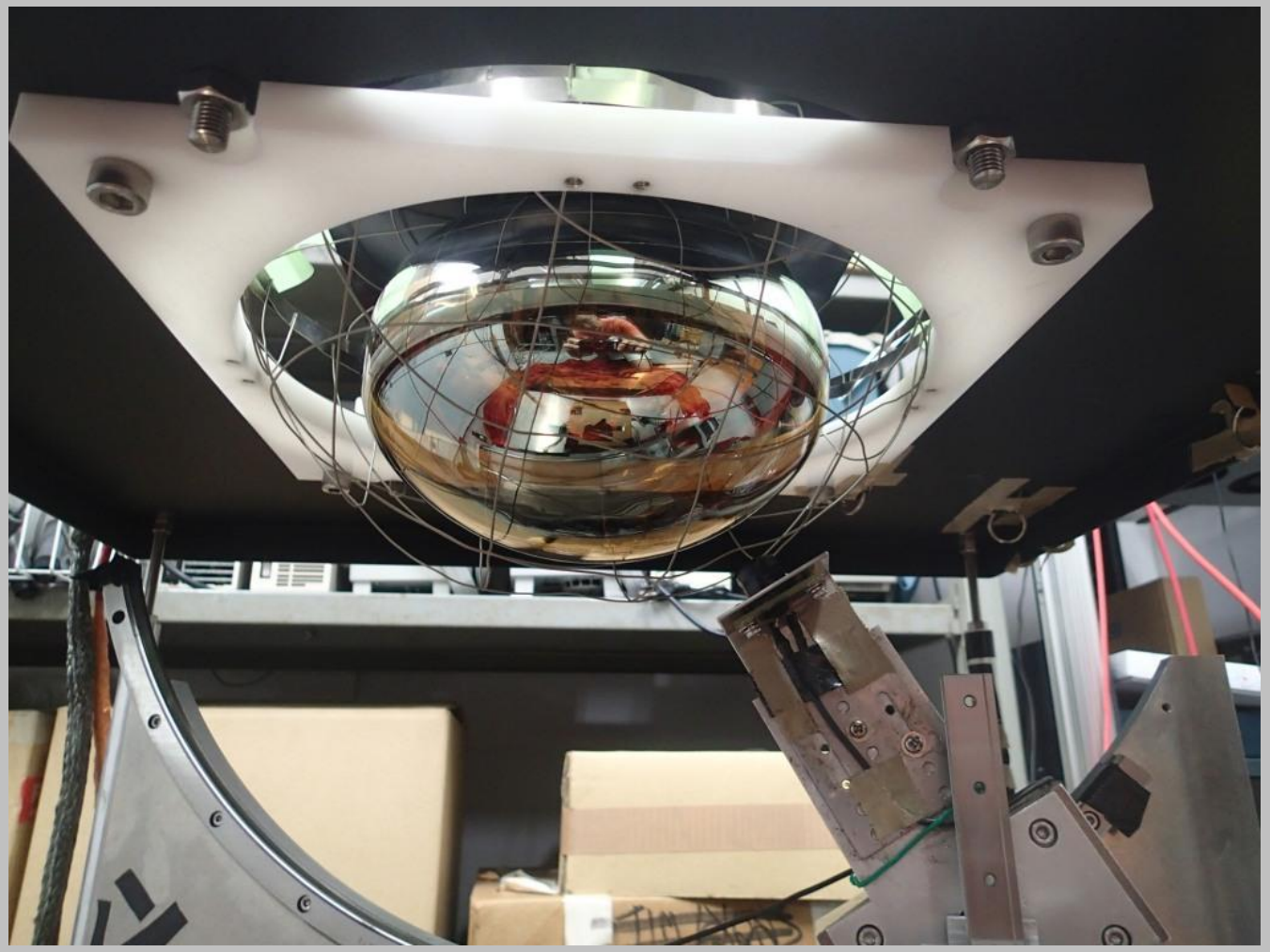
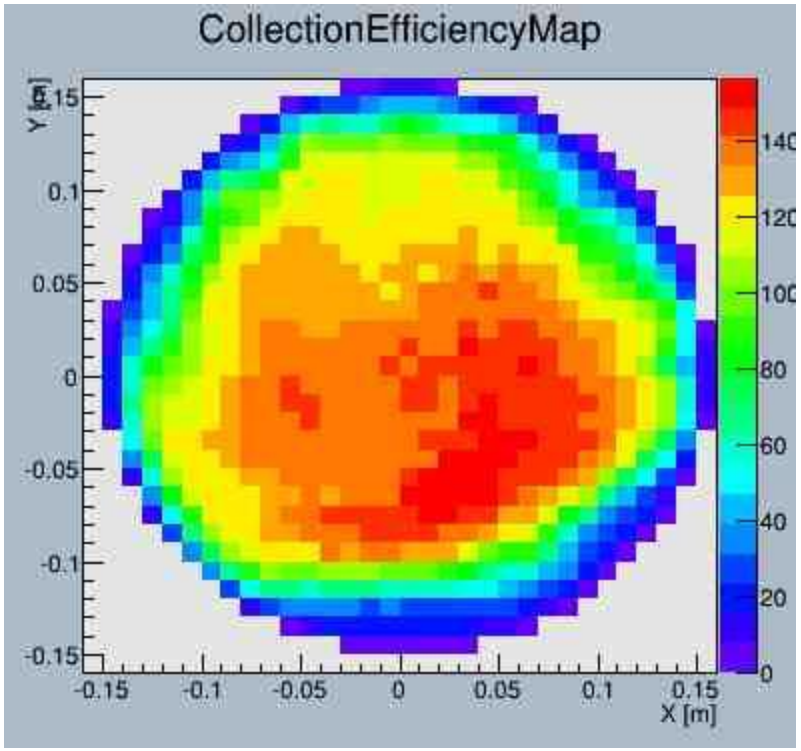


photo-cathode scan

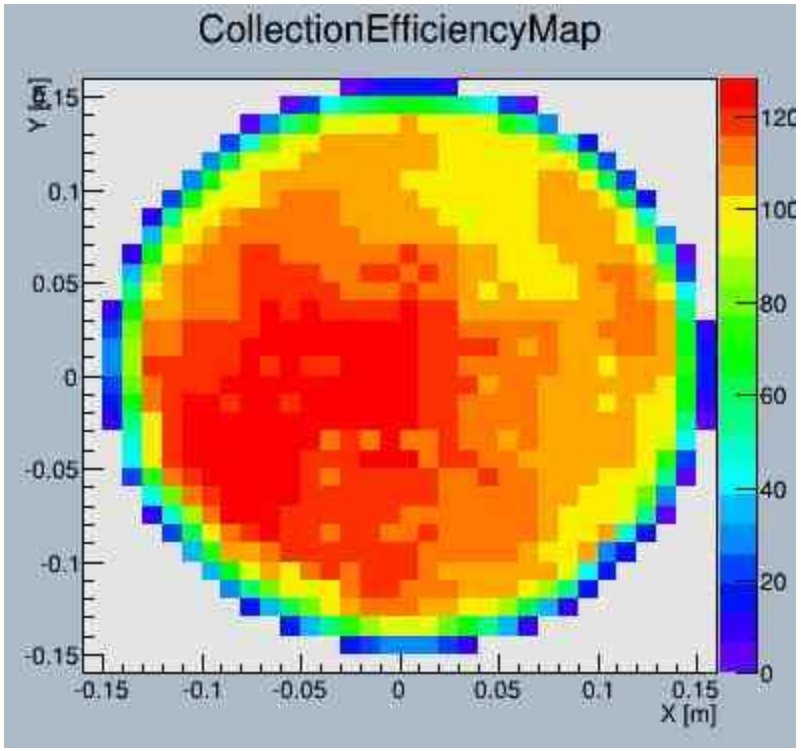
PMT measurement result 2

photo cathode uniformity

The 8” R5912 high-QE



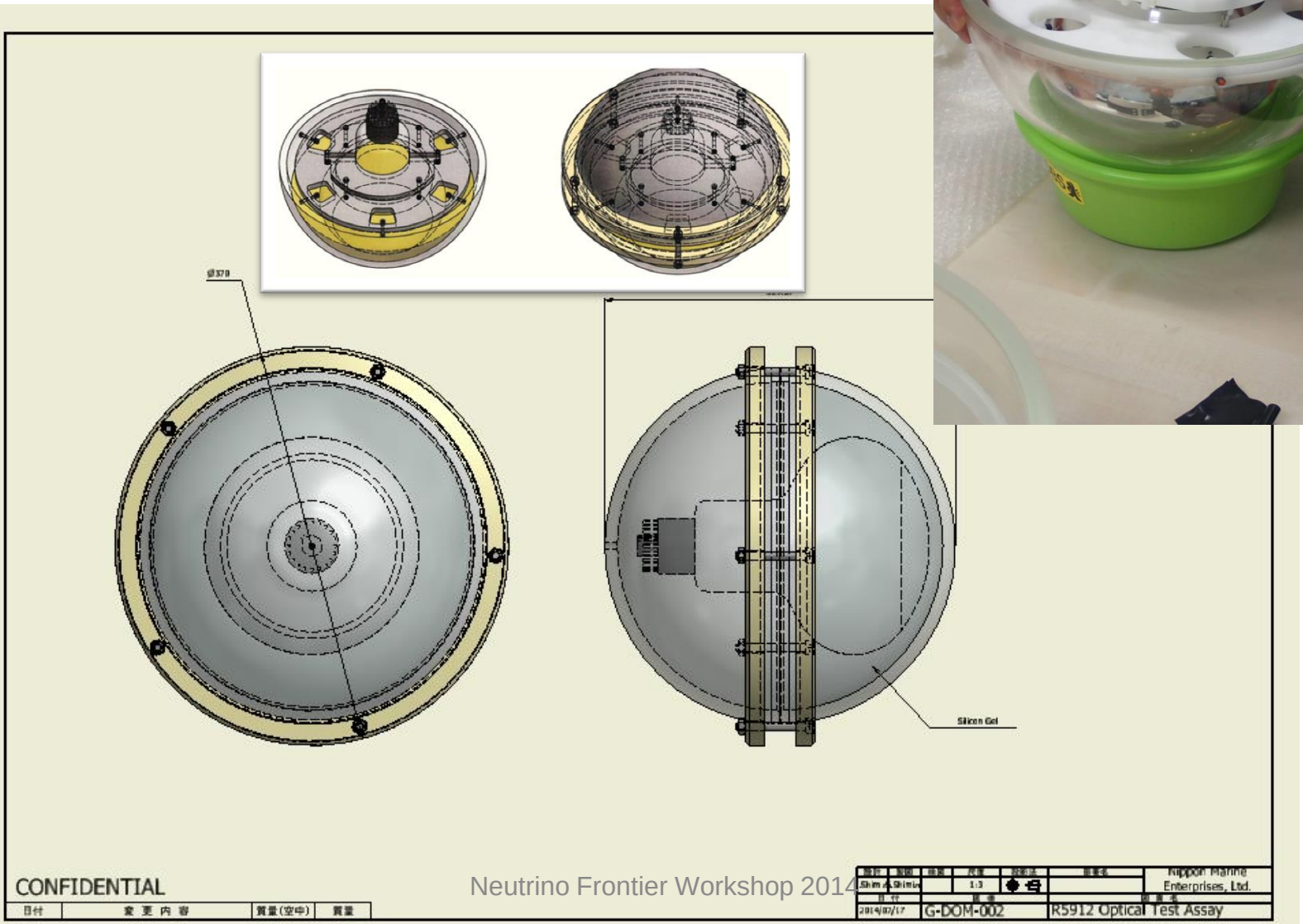
The present IceCube 10” PMT



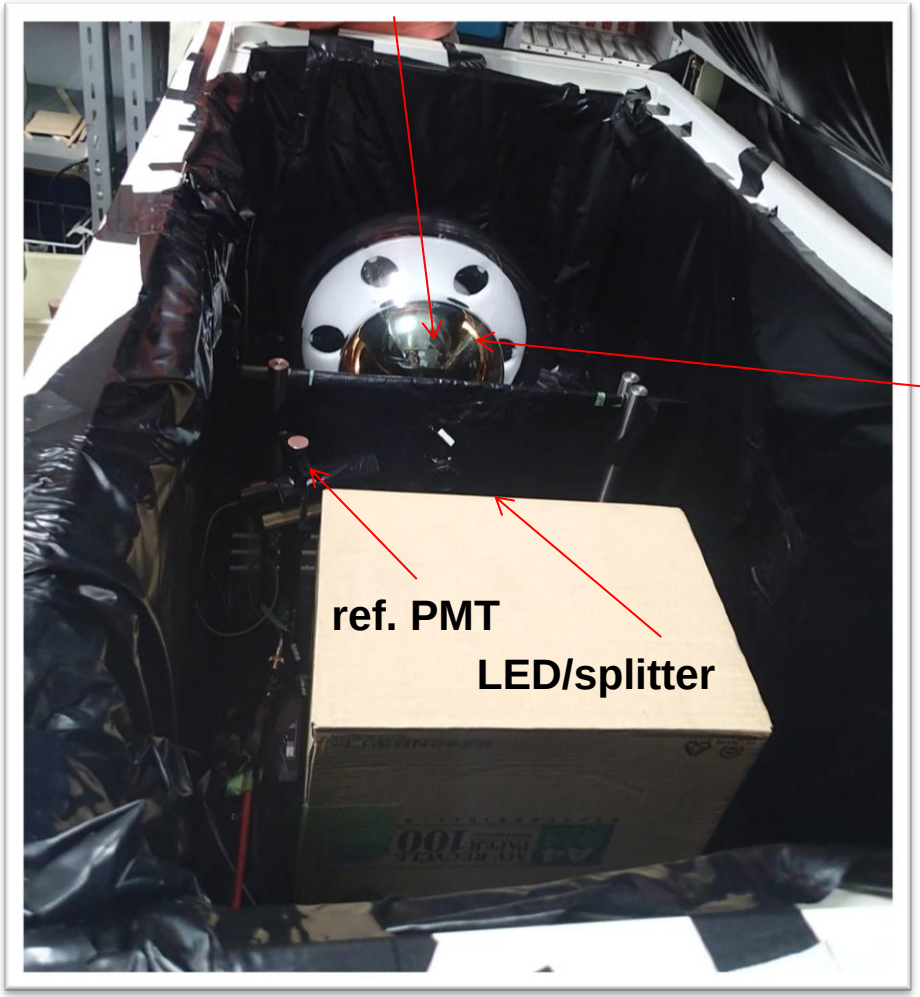
A smaller area, but with the compatible uniformity

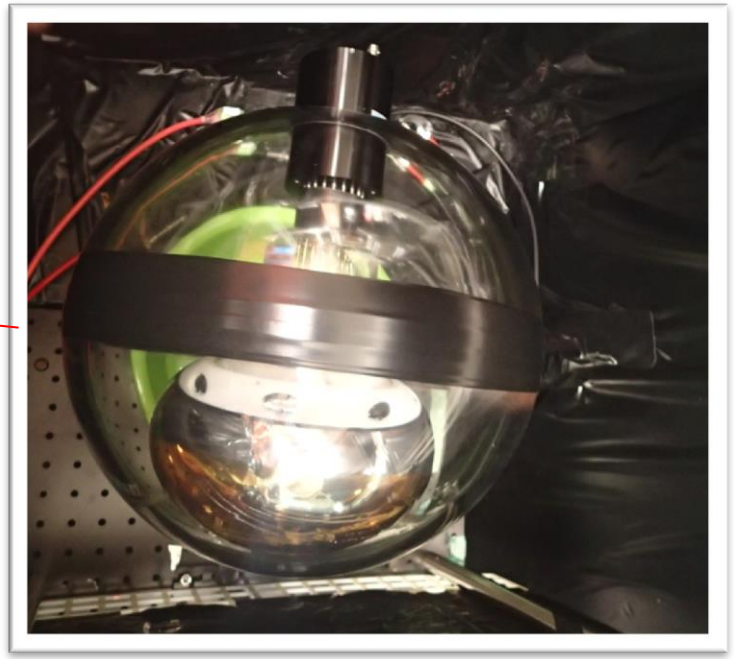
PMT + Glass

- An initial test with a PMT in the spherical glass

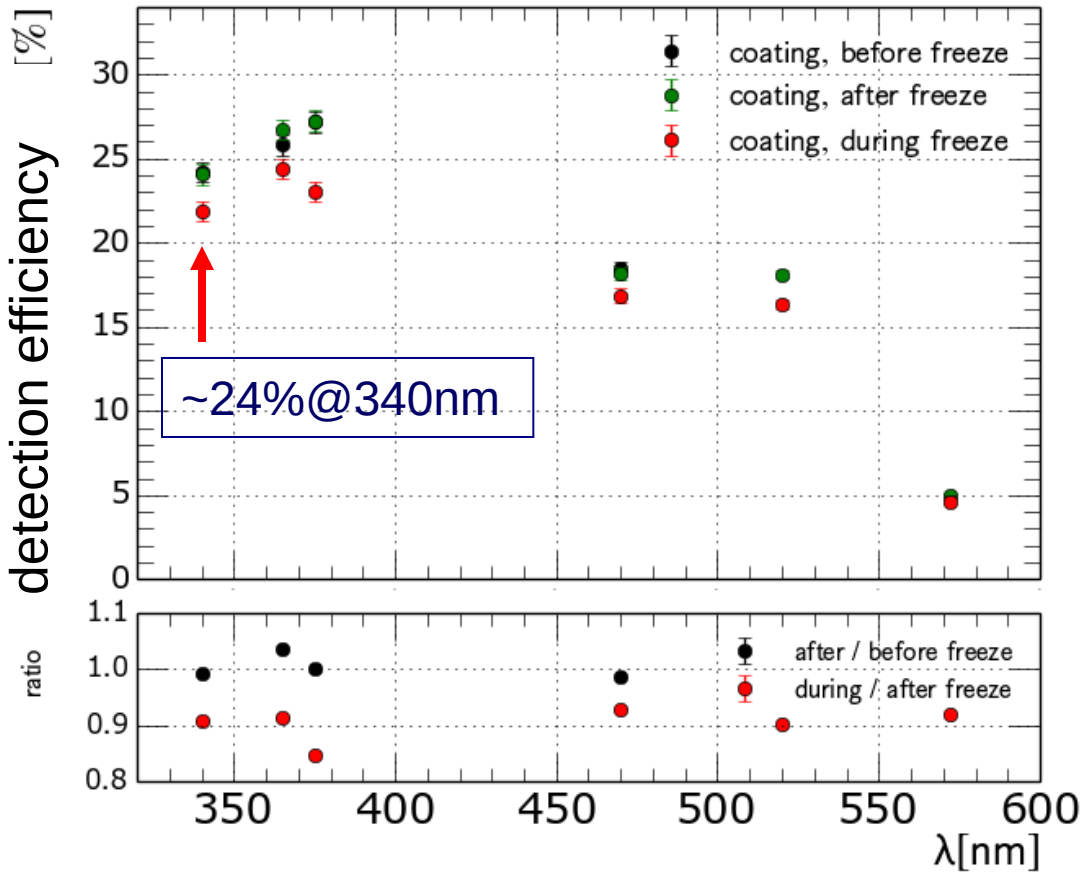


PMT + Glass measurement





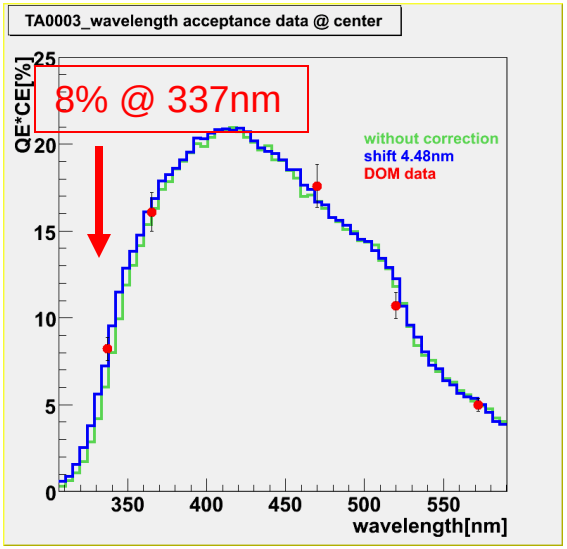
PMT + Glass photon detection efficiency



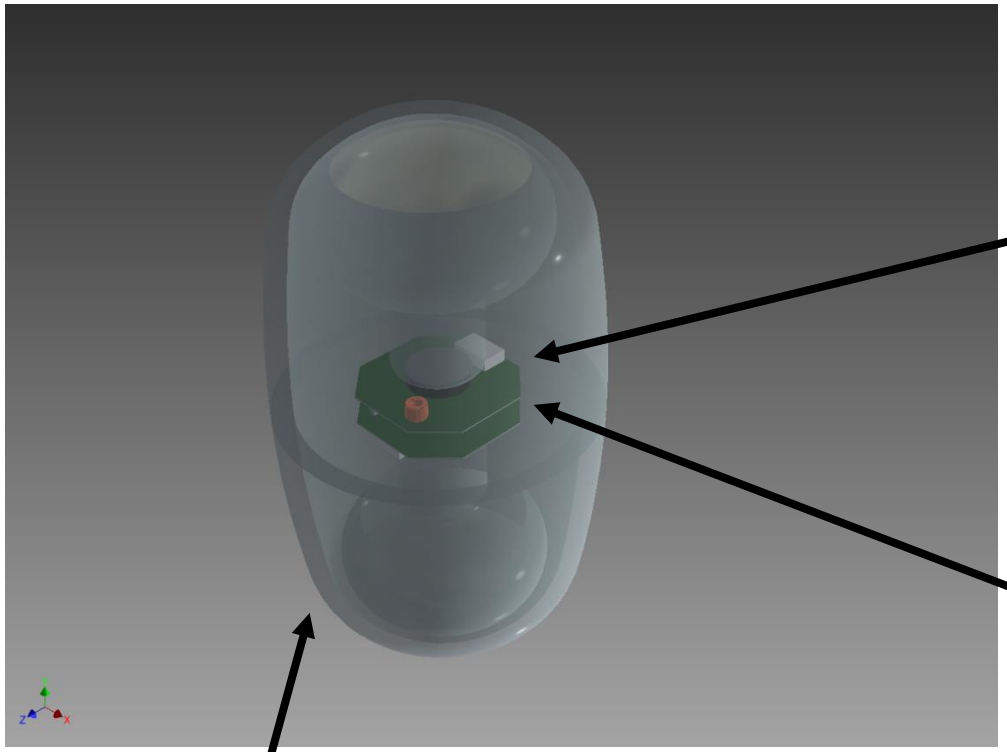
detection eff. @ 340nm

bare PMT 27%
PMT + glass 24 %

The present IceCube DOM

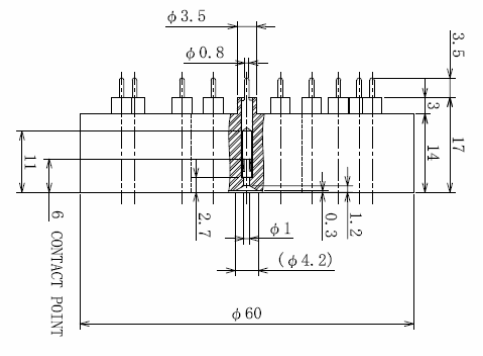


The next: 1st prototype dual PMT module



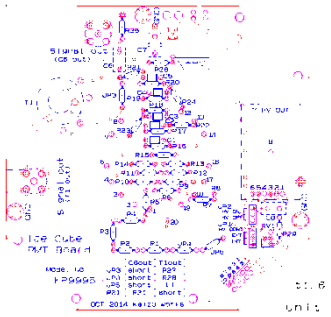
the oval glass sphere housing

design completed



the custom-made PMT base

design completed



the custom-made HV circuit

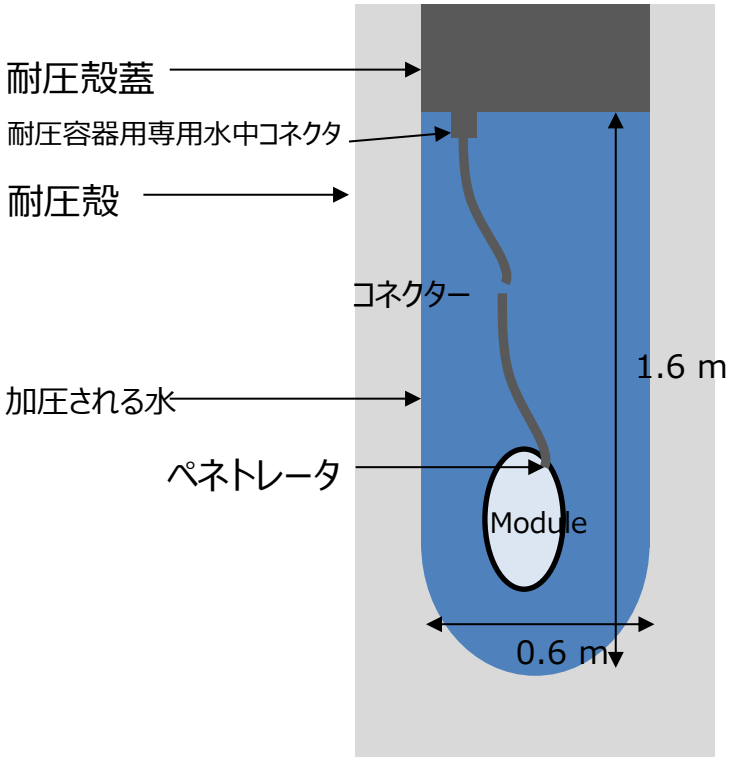
now in production

Tests in the high pressure vessel

- **Glass pressure test with/without penetrator**
- **Module pressure test with working PMT/Gel**

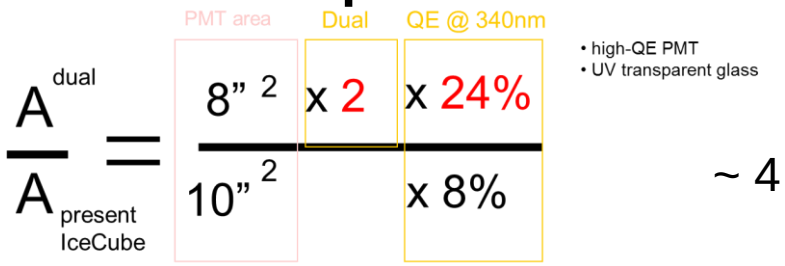
Maximum pressure
147MPa=21320psi

High pressure system @jamstec



Summary and Outlook

- IceCube Gen2/HEX for more discoveries
- Initial R&D module design has achieved ~4 time more Cherenkov photon detection per module



- 1st prototype with ellipsoidal glass with 2 PMTs under construction, will be tested mechanically in harsh environments (pressure, freezing) and optically (QE, noise) in the next months

IceCube-Gen2 White paper

"IceCube-Gen2: A Vision for the Future of Neutrino Astronomy in Antarctica"

is available at arXiv:1412.5106

- International workshop in Germany in December
- Another workshop in US in January