

R&D for the Next Generation IceCube:

IceCube-Gen2

IceCube

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Outline

- What we've learnt 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

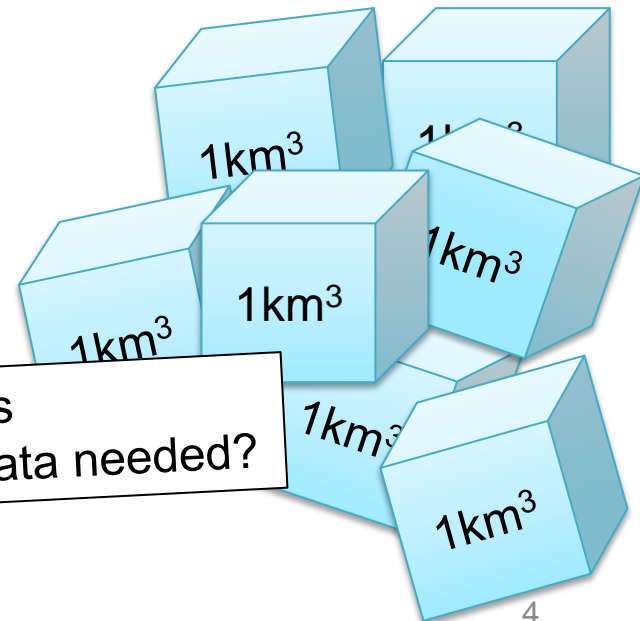
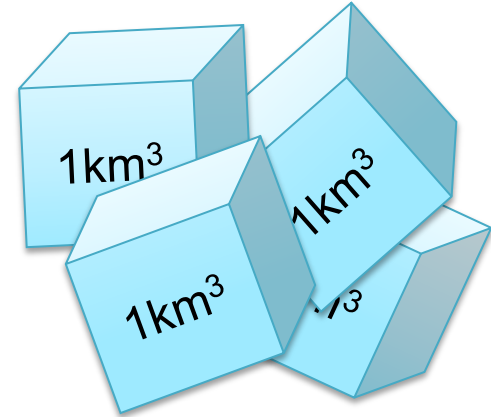
The conceptual  neutrino detector has shown:

- 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 ($E > 10 \text{ PeV}$)
- Precision measurements
 - cosmic neutrino spectra
 - flavors
 - anisotropy
- And more...



Data requirements for the target

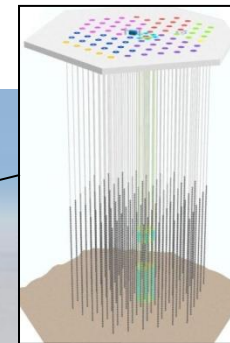
In particular for point sources

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

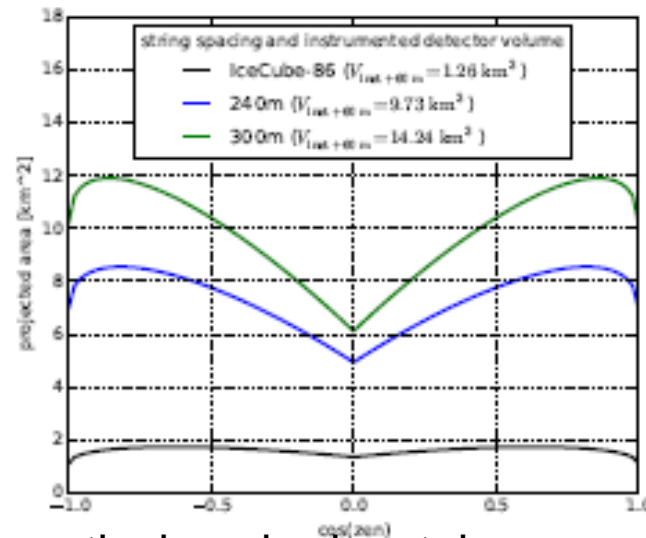
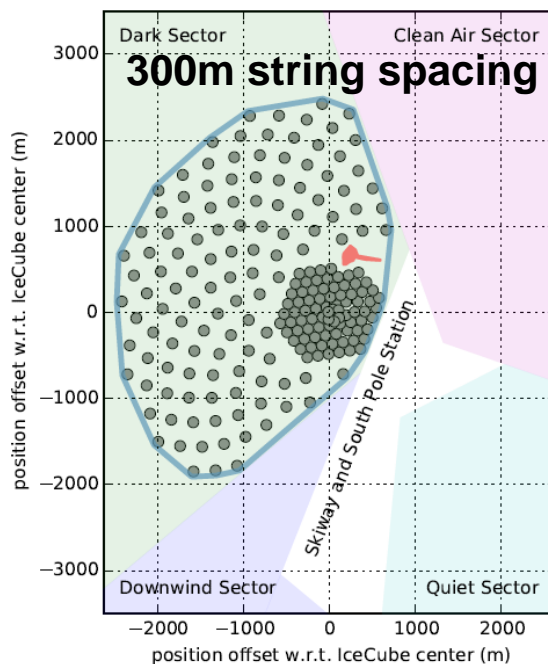
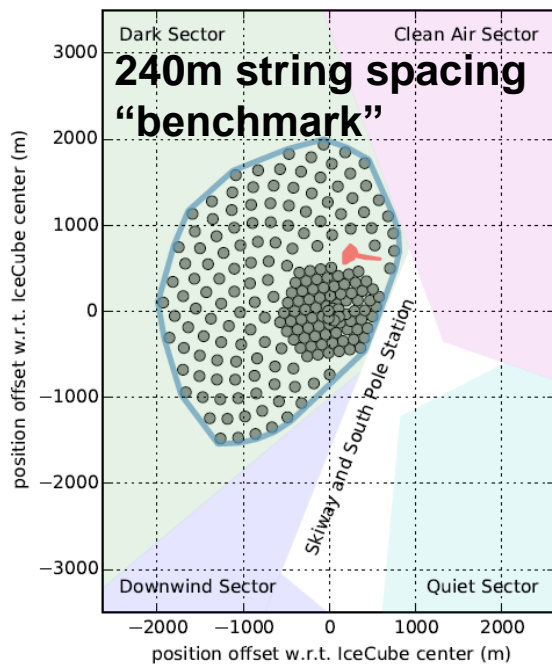


120 more strings

IceCube
78 strings for HE ν

≈ 4 km

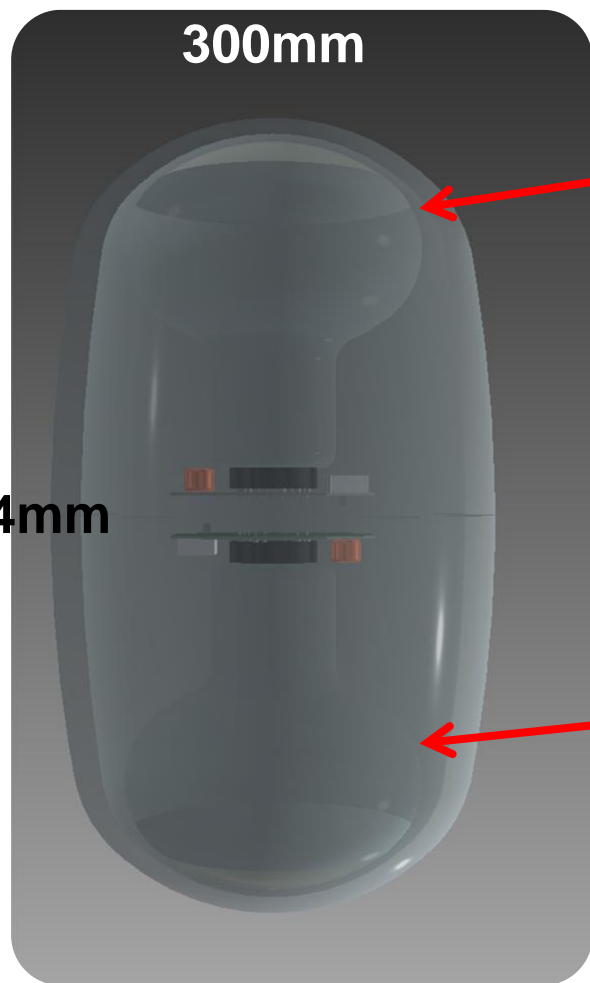
IceCube-86 ($V_{\text{inst}+60\text{ m}} = 1.26 \text{ km}^3$)
 240m ($V_{\text{inst}+60\text{ m}} = 9.73 \text{ km}^3$)
 300m ($V_{\text{inst}+60\text{ m}} = 14.24 \text{ km}^3$)



vertical horizontal

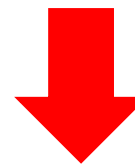
New Optical Modules design proposal from Chiba for IceCube-Gen2

8" SBA PMT R5912-100



to observe

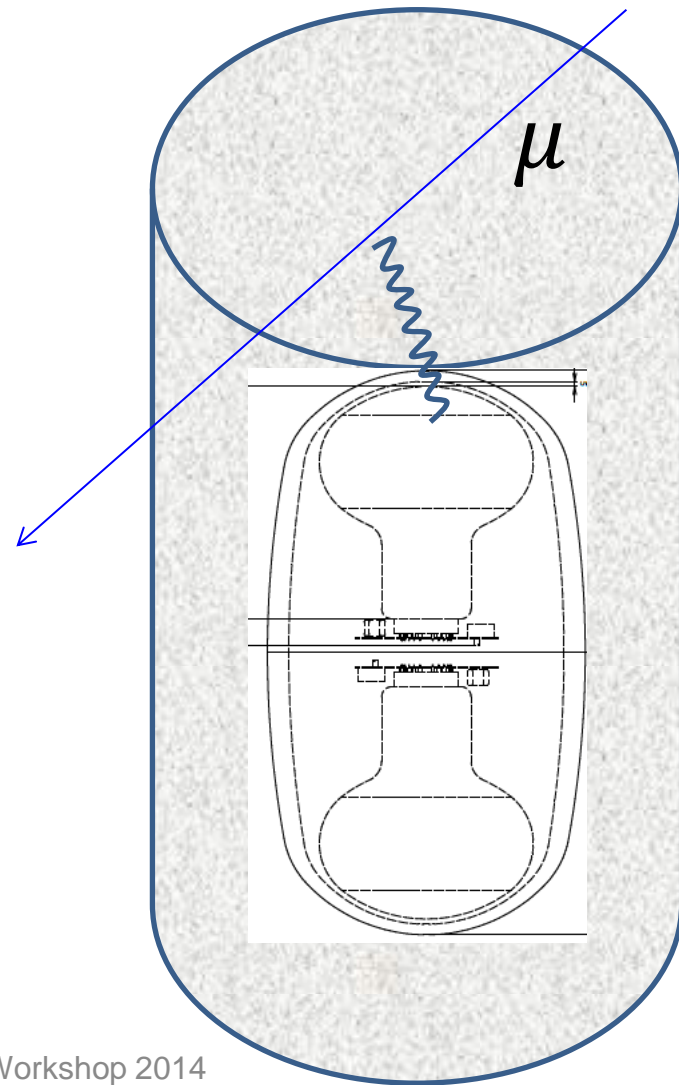
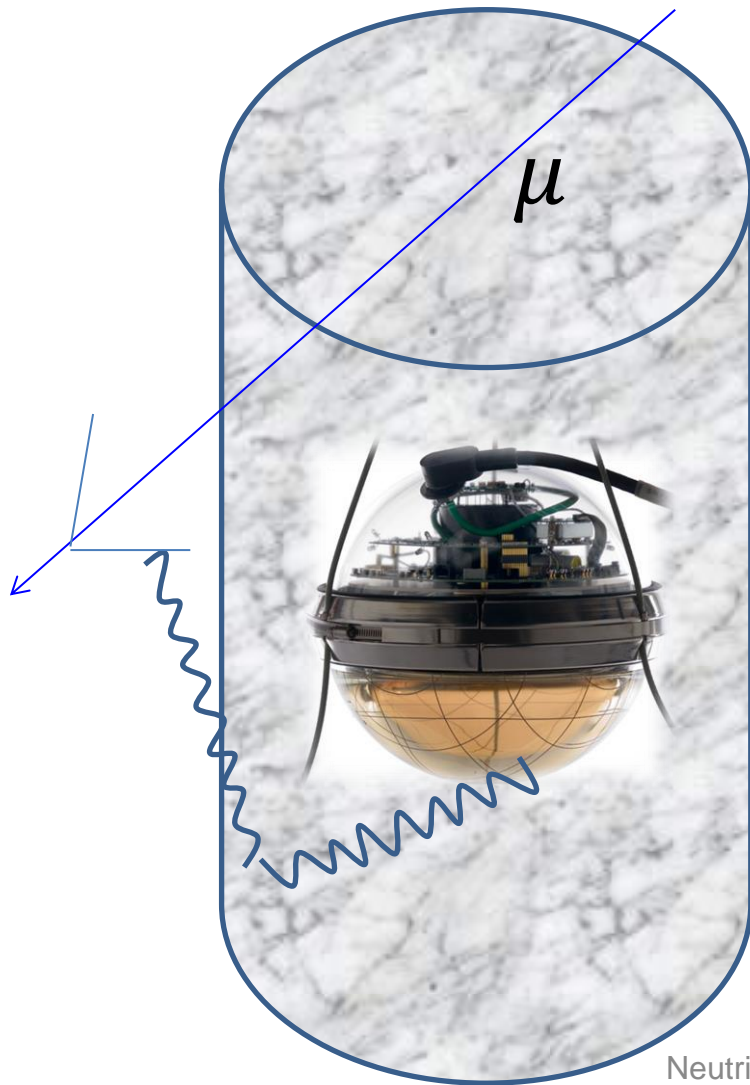
- More signal events
- Better angular resolution
- Better muon veto



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

Up and down symmetry

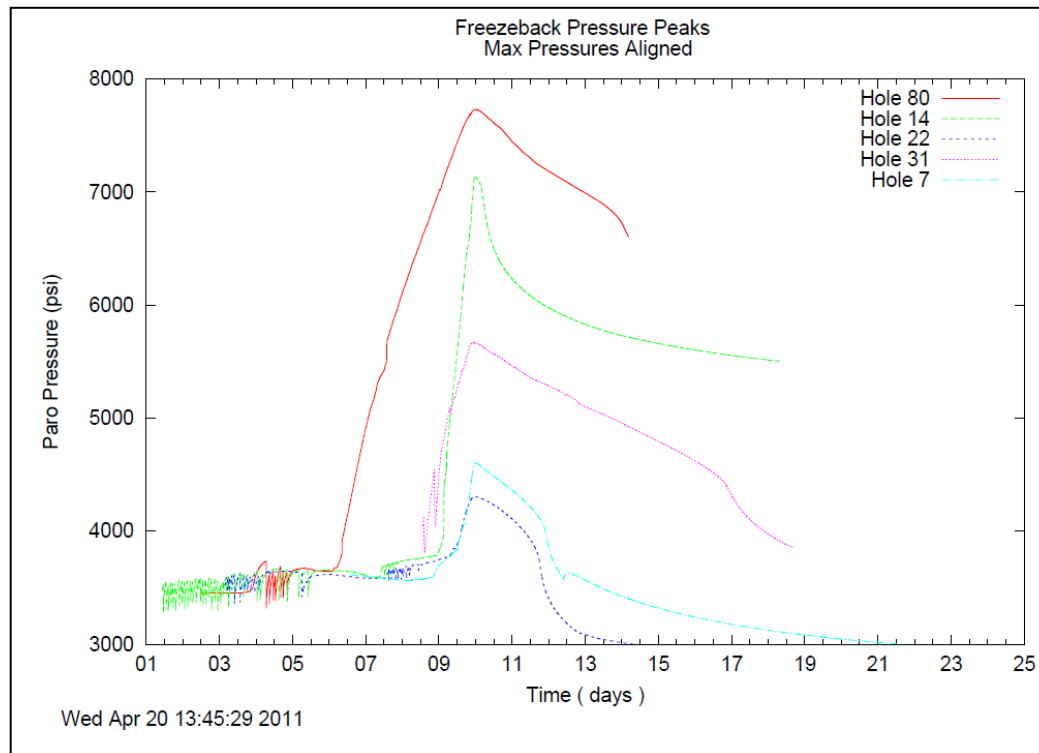
There is a planned upgrade for drill which will make a cleaner ice around the optical module
Down-going muon identification is crucial to reduce the background



Pressure requirements for housing

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

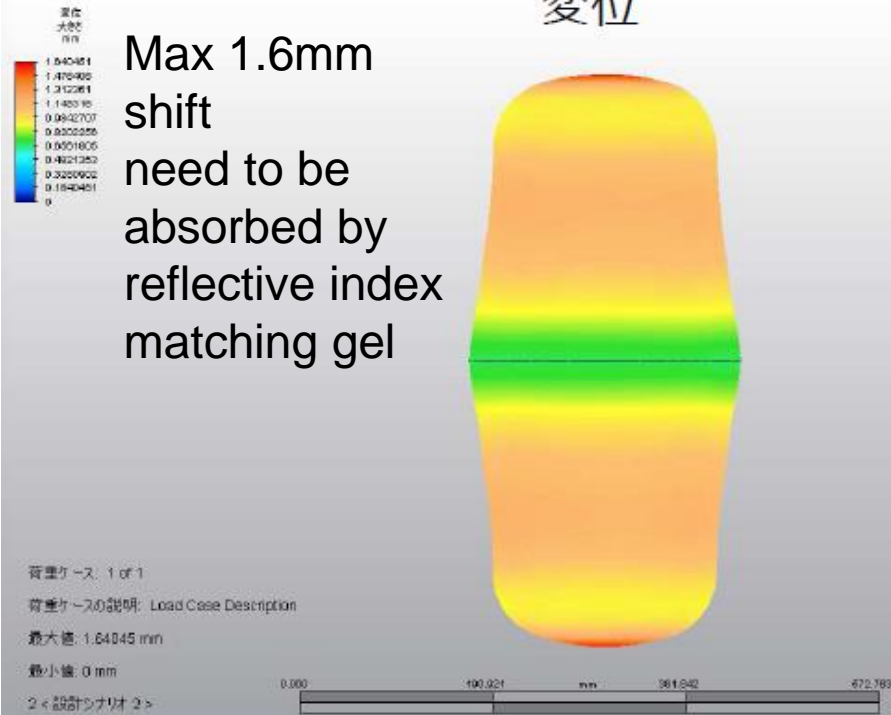
- Overpressure (absolute) 10000 psi (650 bar) for 7 days (During freeze-in process)
- Maximum Operating absolute pressure 3650 psi (250 bar)



Simulations with 10000 psi

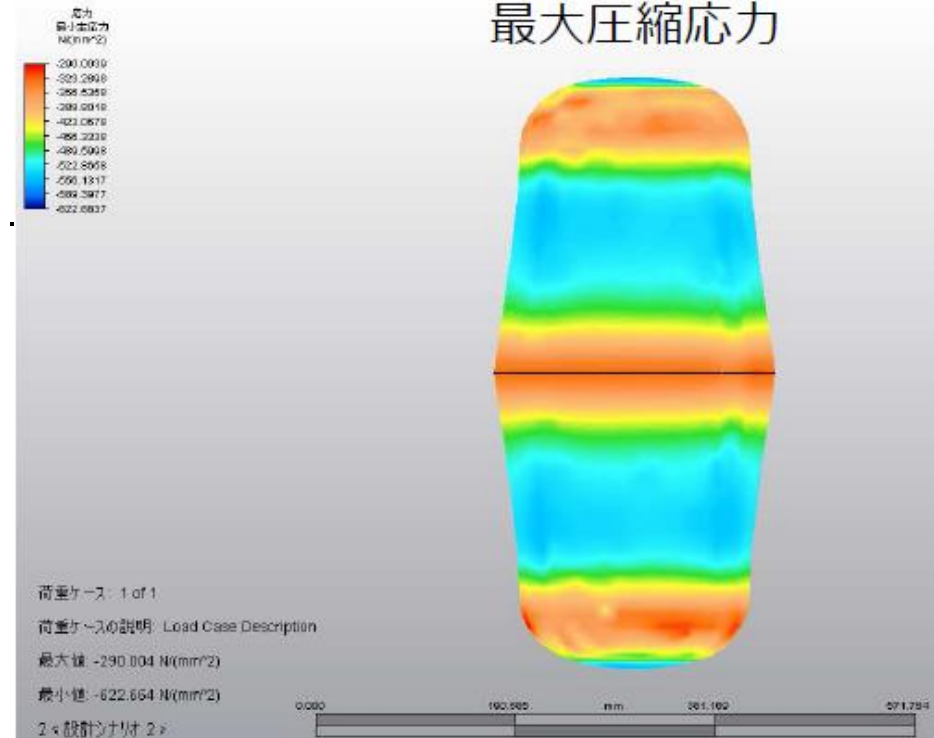
buckling stress

変位

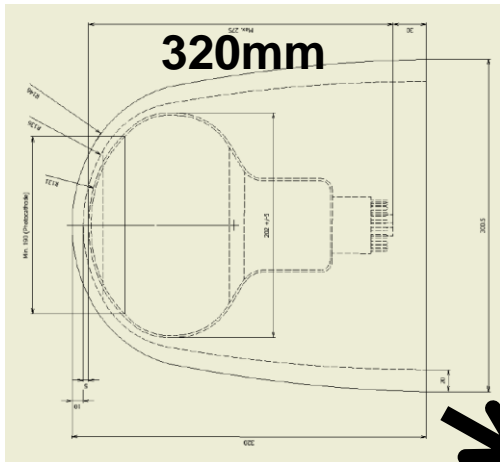


compressive stress

最大圧縮応力



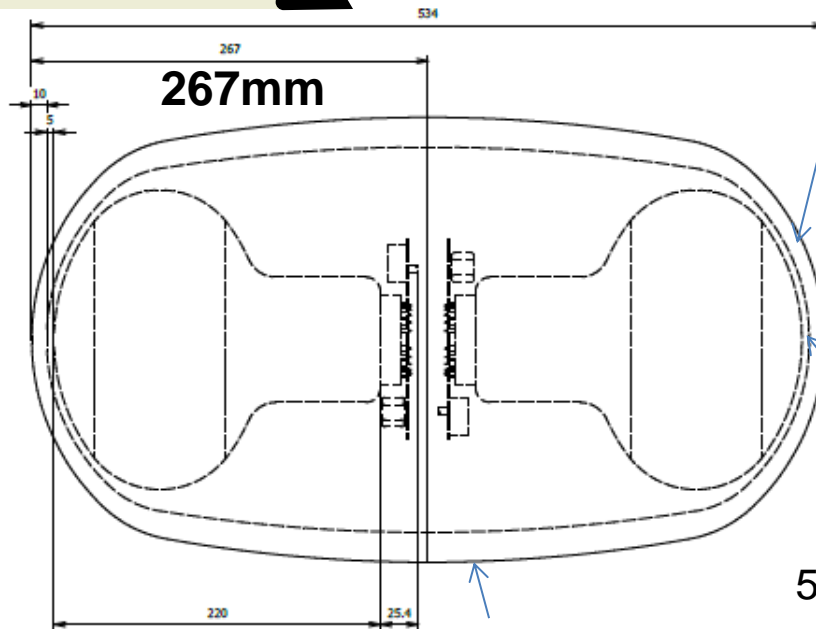
Pressure-resistant glass sphere design



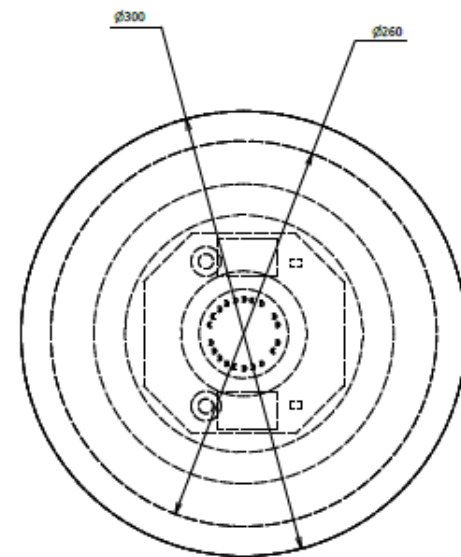
-53mm

- 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



20 mm thickness



5 mm gel thickness

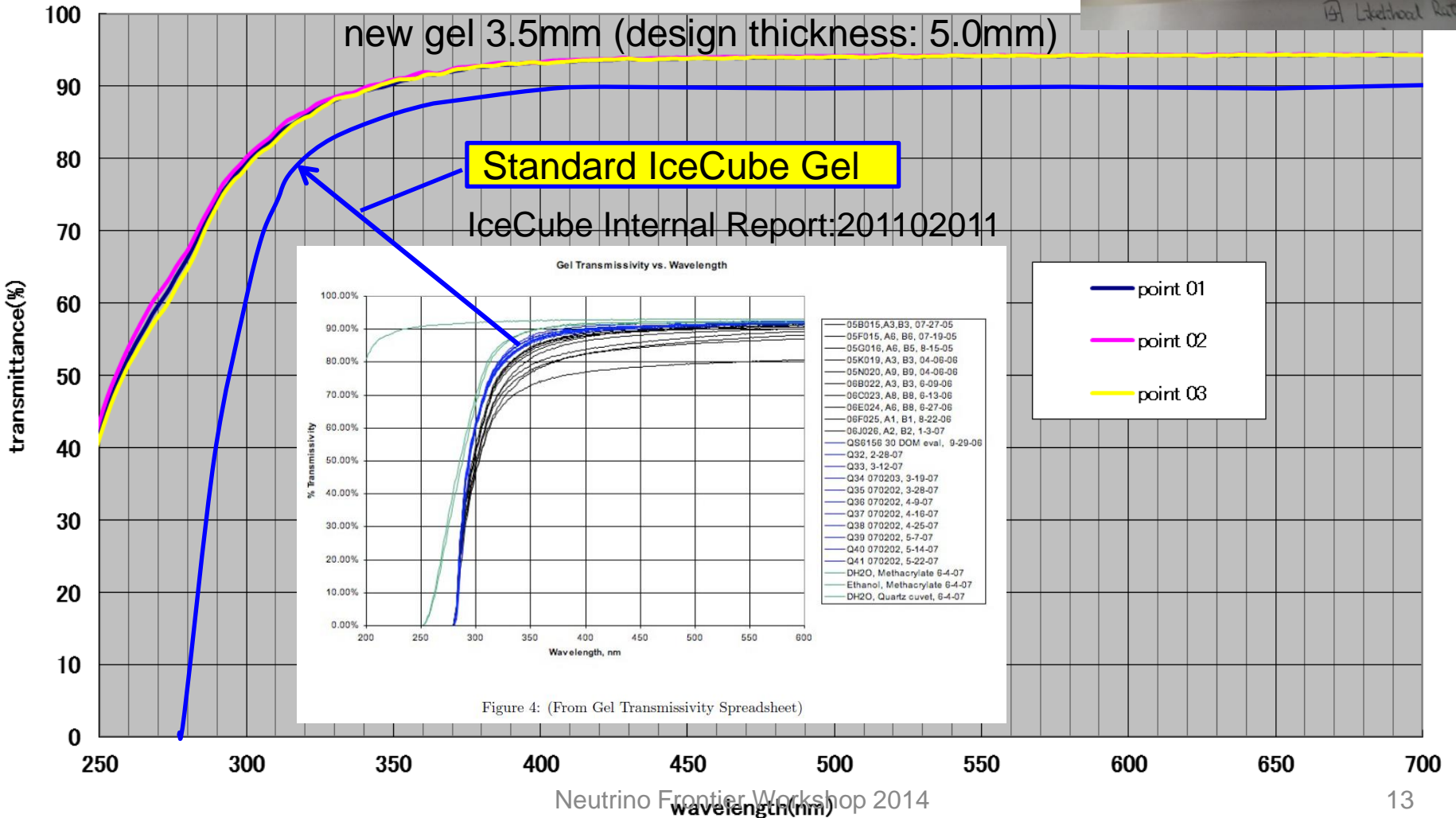
Glass transmittance

- Significant improvements in $<400\text{nm}$,
- More than a factor of 2 improvements in $<300\text{nm}$



Gel transmittance

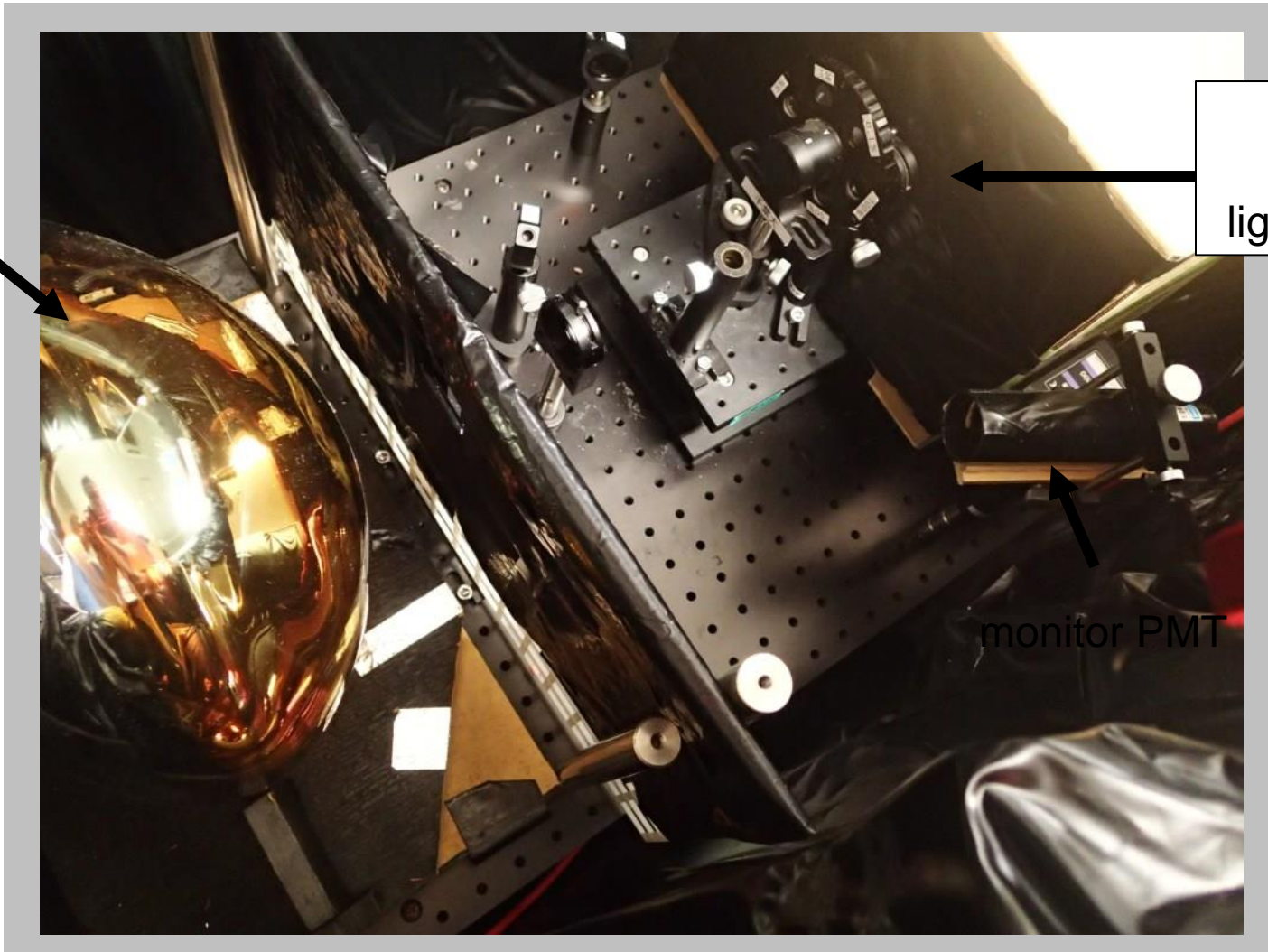
- Overall Improvements over wide range
- Better performance in <300nm



R5912-100 PMT measurement 1

Quantum + Collection efficiency measurement in a freezer box ($\sim -40\text{C}$)

PMT

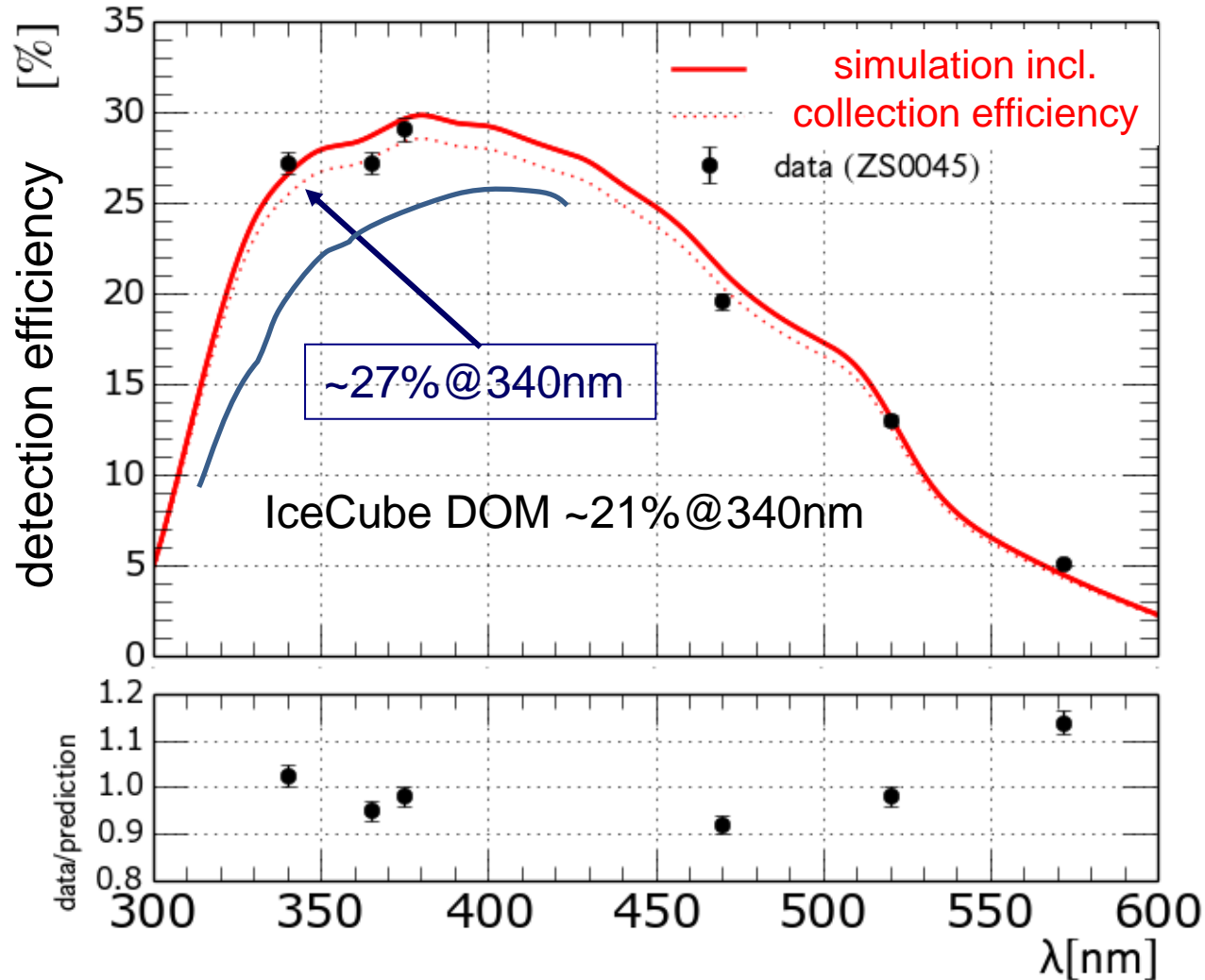


LEDs
+
light pulser

monitor PMT

PMT measurement result 1

photo detection efficiency = QE x CE



PMT measurement 2

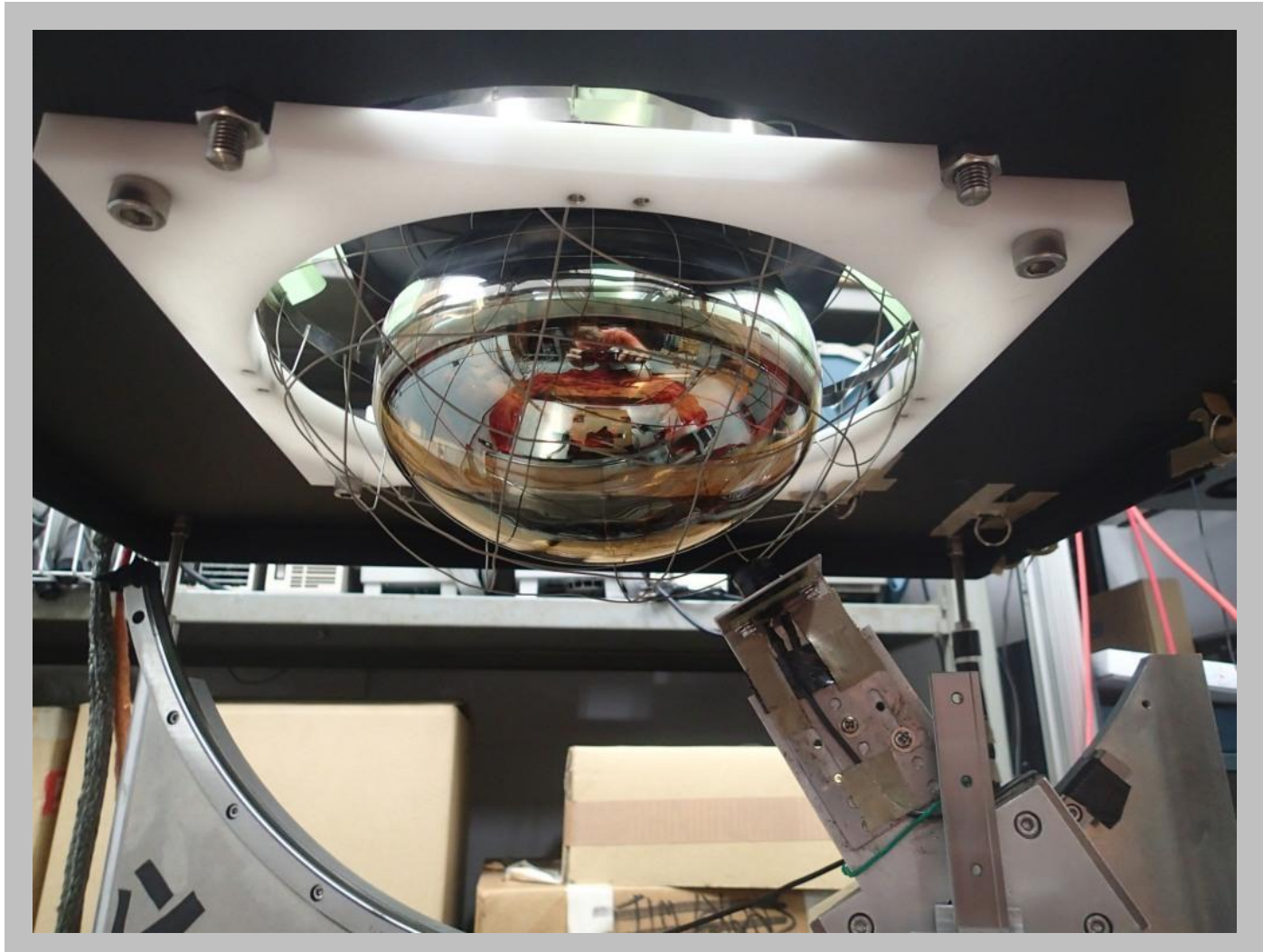


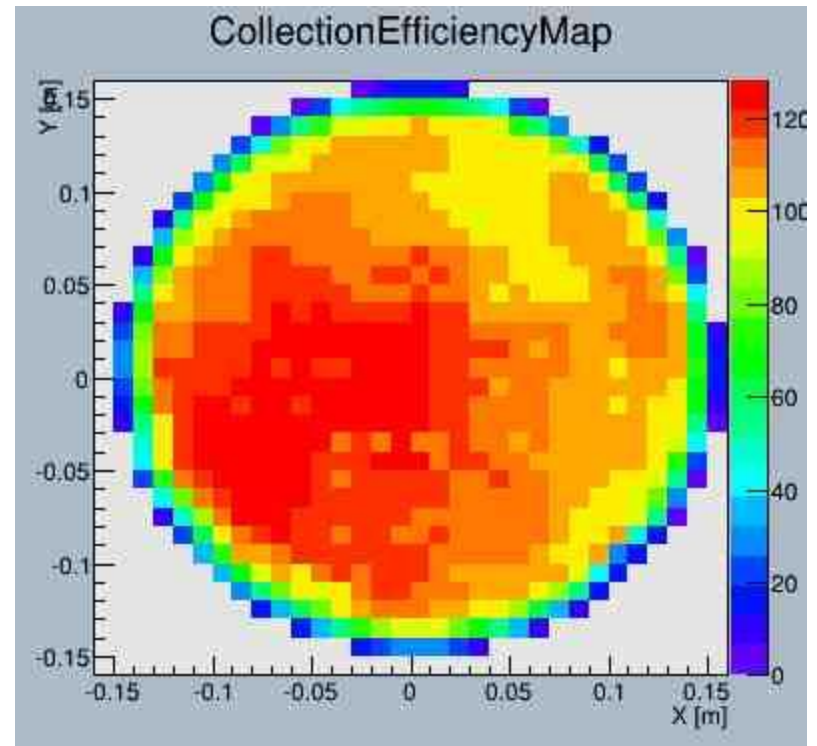
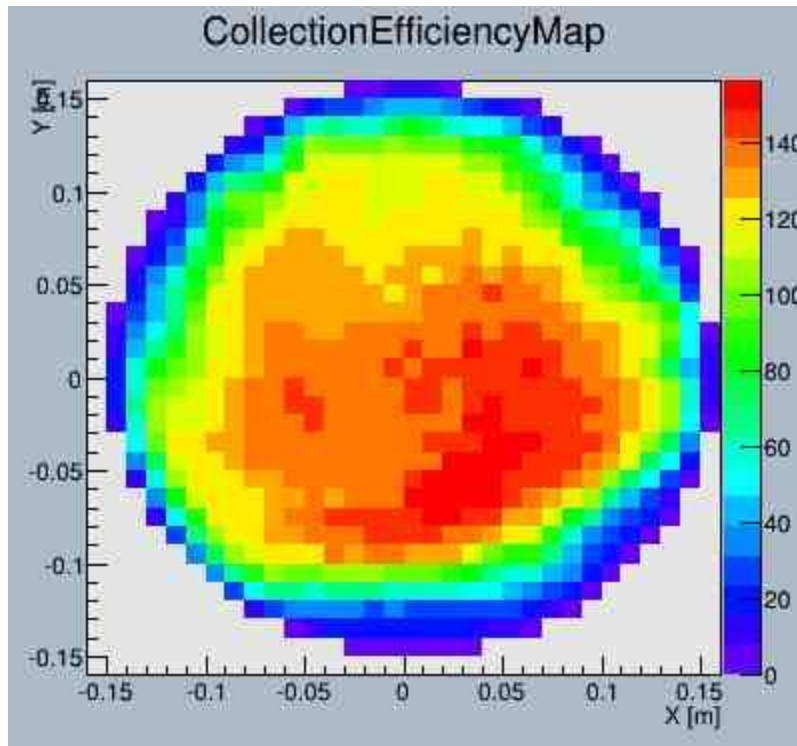
photo-cathode scan

PMT measurement result 2

photo cathode uniformity

The 8" R5912 high-QE

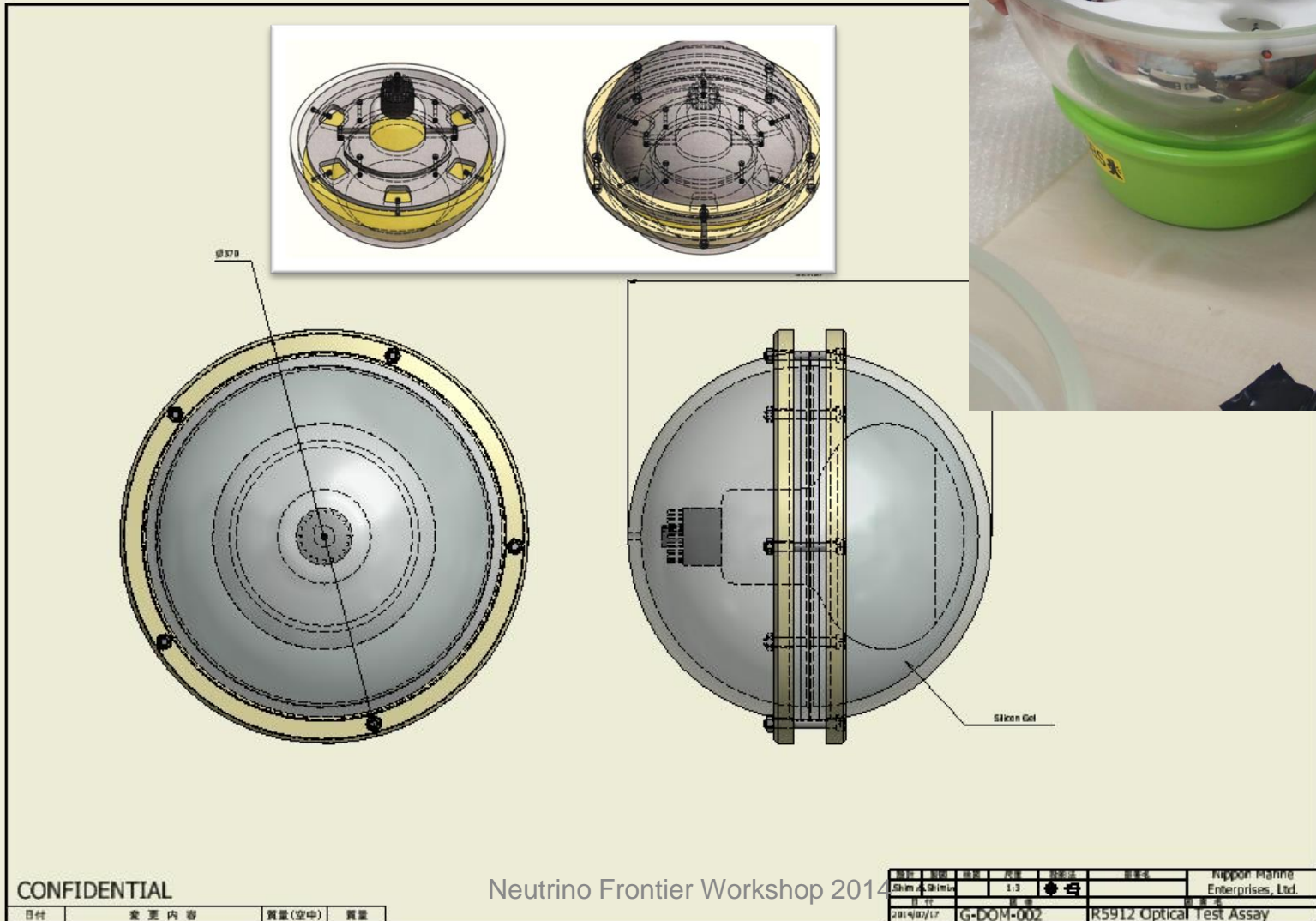
The present IceCube 10" PMT



A smaller area, but with the compatible uniformity

PMT + Glass

- An initial test with a PMT in the spherical glass



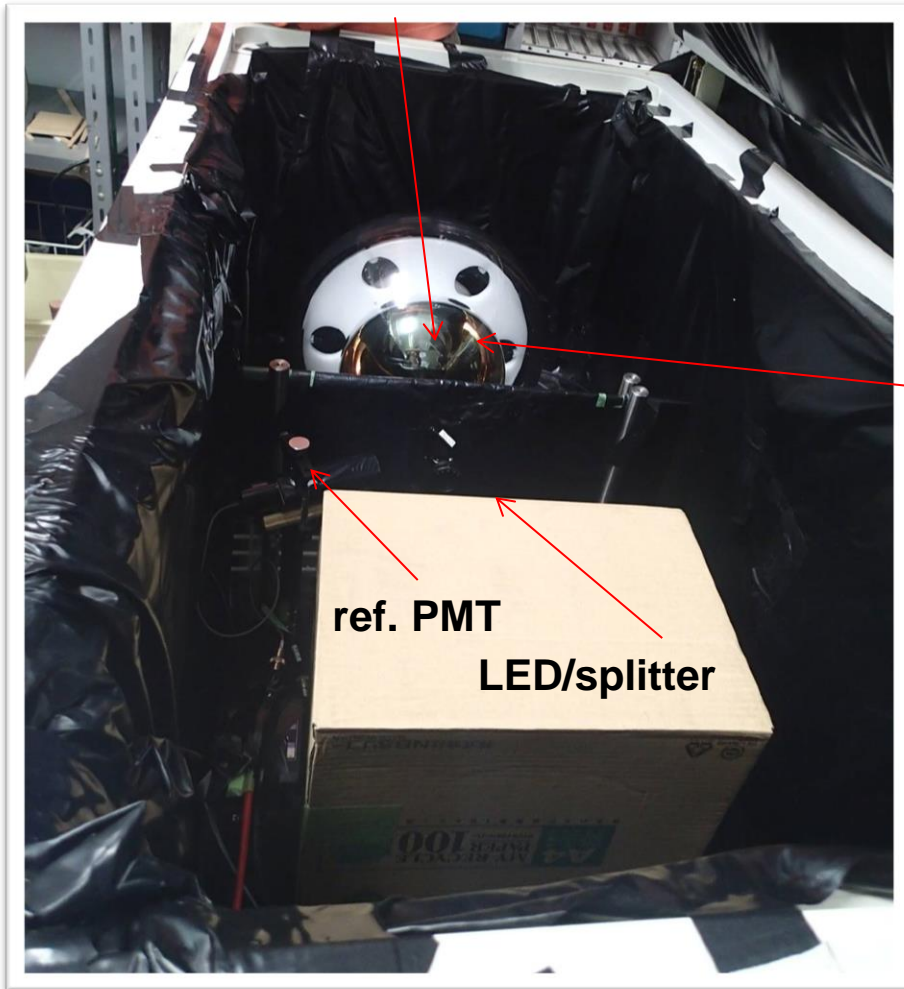
CONFIDENTIAL

Neutrino Frontier Workshop 2014

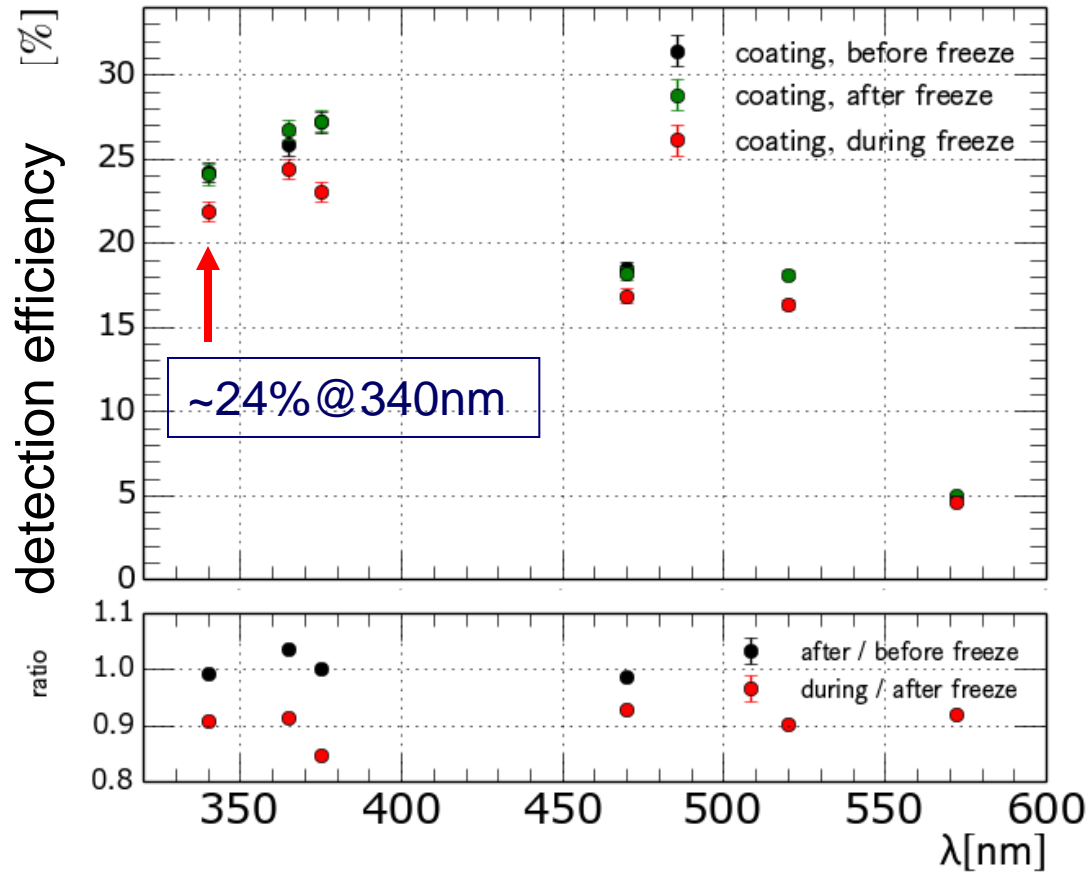
図名	図号	図尺	図式	図例	図説
Shimizu Shimizu		1:3	◆	◆	Nippon Marine Enterprises, Ltd.
日付	変更内容	質量(空中)	質量		
2014/02/17	G-DOM-002				R5912 Optical Test Assay

PMT + Glass measurement

Glass + PMT



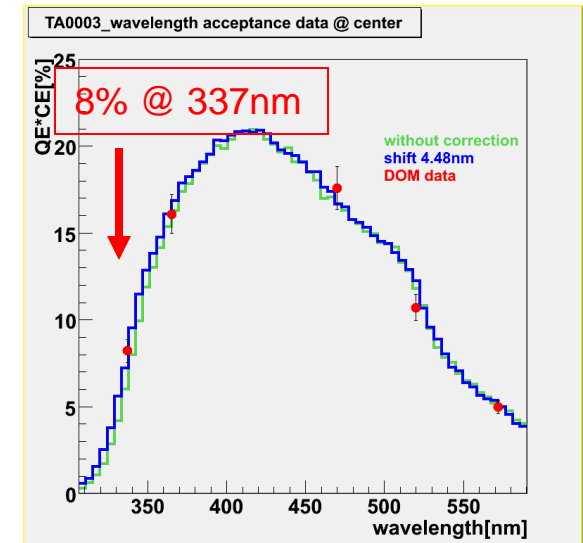
PMT + Glass photon detection efficiency



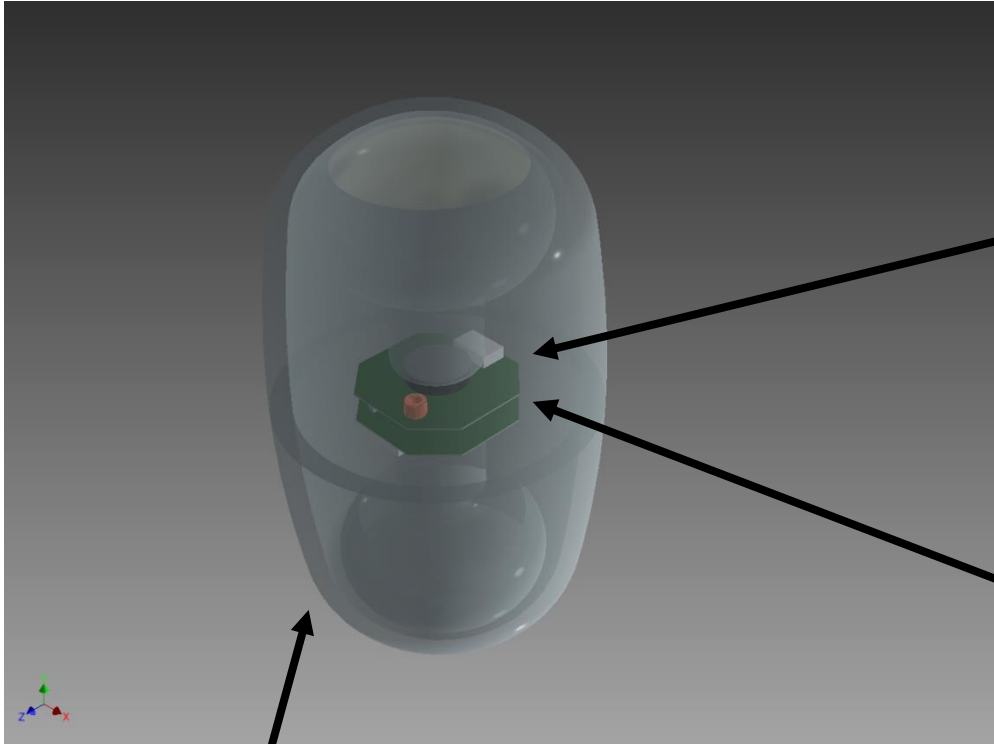
detection eff. @ 340nm

bare PMT 27%
PMT + glass 24 %

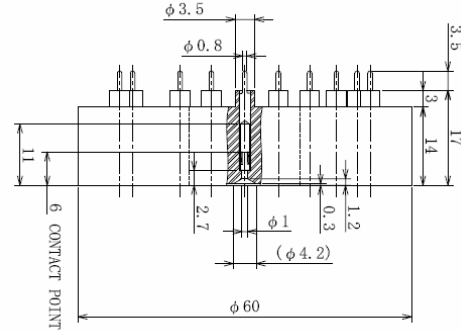
The present IceCube DOM



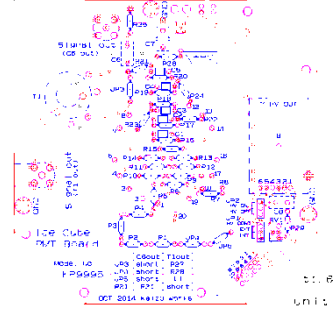
The next: 1st prototype dual PMT module



the oval glass sphere housing
design completed



the custom-made PMT base
design completed



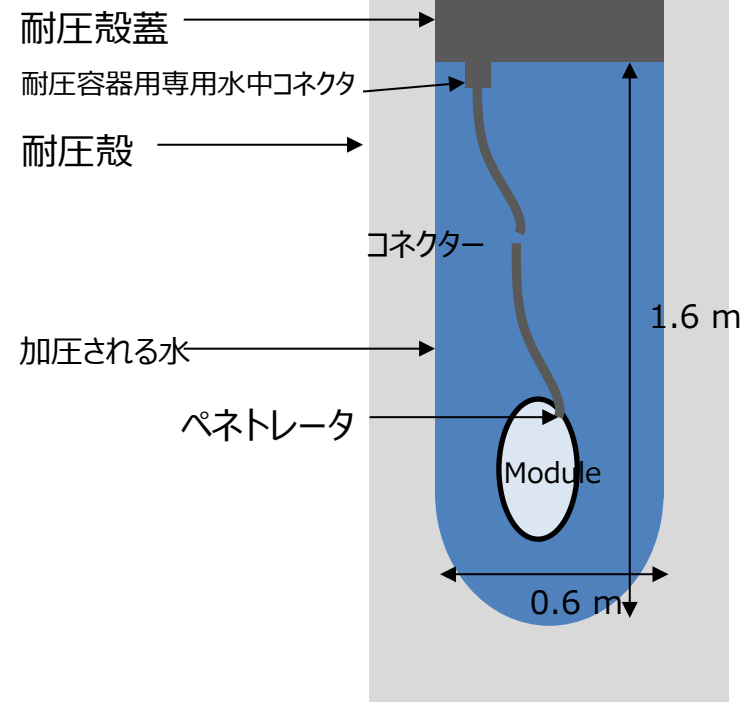
the custom-made HV circuit
now in production

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

$$\frac{A^{\text{dual}}}{A^{\text{present IceCube}}} = \frac{8''^2 \times 2 \times 24\%}{10''^2 \times 8\%} \sim 4$$

PMT area Dual QE @ 340nm

- high-QE PMT
- UV transparent glass

- 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](https://arxiv.org/abs/1412.5106)

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

The screenshot shows a web page with a dark blue header. The main title is "Detector Design and Technology for Next Generation Neutrino Observatories". Below the title, it says "8-10 December 2014 Aachen" and "Europe/Berlin (timezone)". There is a search bar with the word "Search" next to it. On the left side, there is a navigation menu with the following items: Overview, Organisation, Timetable, Registration (with a sub-item "Registration Form"), List of registrants, Accommodation, How to reach the HAP Workshop?, and Poster. The main content area is titled "DESY, Zeuthen" and contains the following information: **Dates:** from 08 December 2014 09:00 to 10 December 2014 15:00; **Timezone:** Europe/Berlin; **Location:** Aachen, Haus Königshügel, der RWTH Aachen, Melatener Str. 31-35, 52074 Aachen, Room: ; **Material:** Poster; **Additional info:** Bring together the German and international astroparticle community for a coherent effort towards next generation Neutrino Telescopes. Below this, there is a list of topics: Neutrino detection from MeV to EeV energies, Air shower physics with surface detectors, Veto strategies, and Optical sensor development. At the bottom left, there is a "Support" link and a "Read Indico.desy.de" button.