Pressure-resistance of photo-sensor and cover

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Overview

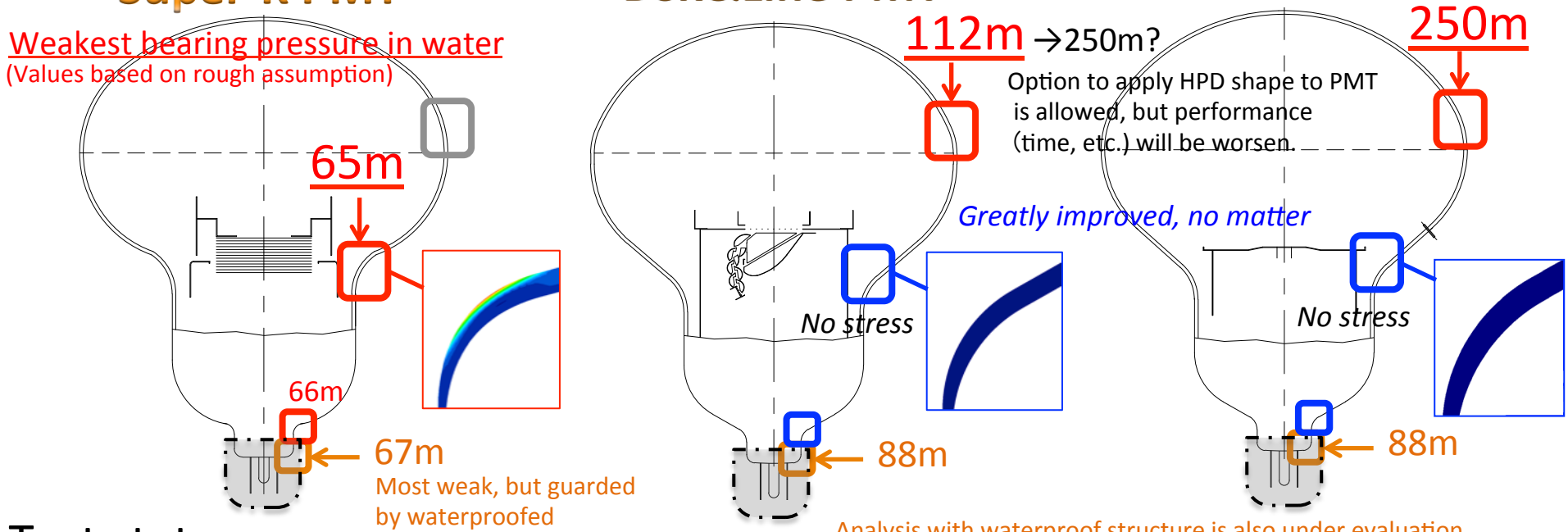
- It is critical to operate HK for a long period by **photodetectors** with safety design and test, and **protective cases** to avoid chain implosion.
  - ***We never repeat the accident occurred at Super-K.***
- Height of HK tank is limited by pressure resistance of photodetector.
  - SK : 40m, HK (baseline) : 50m, HK deepest option : 100m
  - New photodetectors have higher water bearing pressure than Super-K PMT in design. (but how deep?)
- Possible options and its concern, as well as strategy for safety test, is reviewed.

Stress analysis of 50cm size

Stress analysis on 50cm glass valves

Both new 2 PDs show good improvements.

Super-K PMT << **Box&Line PMT** << **HPD**



Analysis with waterproof structure is also under evaluation.

Test status

16/4727 SK PMTs (0.3%) were broken in 0.67MPa test

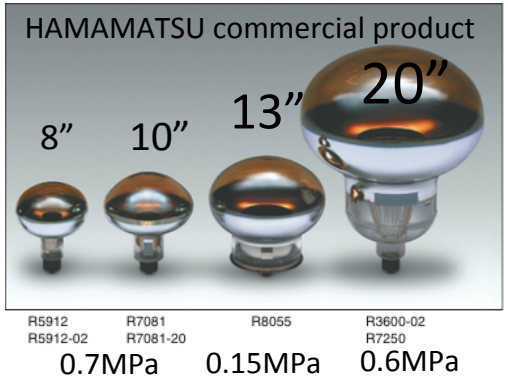
Tested at once
w/o broken in 0.92MPa
(Maximal setting)

Tested at once
w/o broken in 0.92MPa
(Waterproofed version is not available yet)

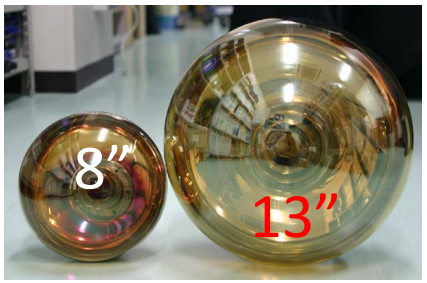
- It just shows design, but we need a test to know actual performance.
  - Ability of test facility is not sufficient now to confirm more tolerance for deeper water option.
- Should keep enough room on safety factor as much as possible with considering few failure, because quality control is difficult on manufacture by hand.
  - Mass test and protective case are important to minimize failure.

Small photosensor option

- Even if 50 cm PDs are not sufficient as for high pressure resistant, deep water tank is possible with small photosensor.
  - If both cost and detection performance is reasonable…
- Stress for spherical valve ∝ (Static pressure)×(Radius)/(Thickness)
  - Smaller radius would bring higher bearing pressure.
- 12 – 13 inch (30–33 cm) PDs are available in several manufacturers.



HPD in previous R&D



11” ETEL/ADIT PMT

- Still 50cm PD R&D will proceed as baseline size.
  - Similarity version of new 50 cm PDs would be also possible for small one.
    - Performance would improve and be equipped with high pressure tolerance

Past study of protective case in SK

- 3 options were tested in SK tank with varied thickness under 36m water depth by demonstrating protection from implosion.
- All acrylic case
  - Sufficient to protect PMT
  - Might be hard to keep good quality control
  - Quality of assembling is concerned.
- Stainless steel + acrylic case
  - Too heavy to be attached on SK wall structure with sufficient protection
- FRP + acrylic case
  - Low Rn contamination expected
  - Num. of layers of FRP is also surveyed.
  - adopted for SK case finally

All acrylic case

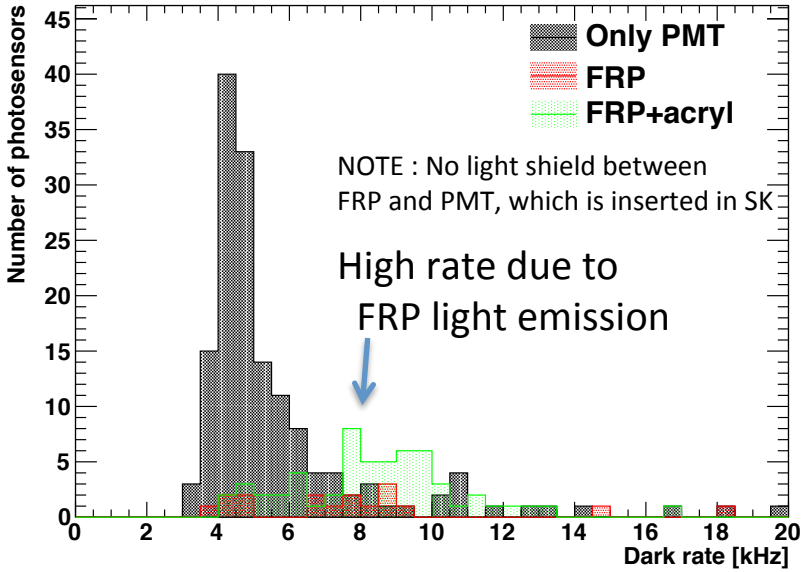
Stainless steel

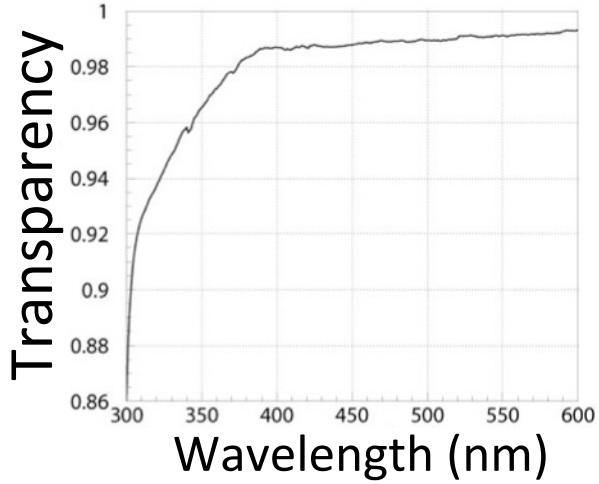
(pipe ver.)

Case in Super-K

- FRP - Fiber Reinforced Plastics
- Acrylic face with good transparency
  - Small holes make shockwave weak w/o breakdown of case
- Found out to be undesired for low energy events.
  - Light from FRP is protected by black sheet in SK

Dark rate example in 200ton water tank

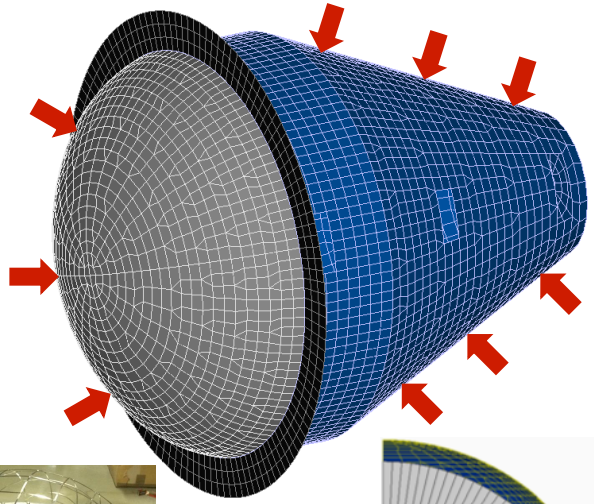




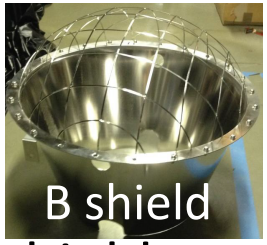
Designed after 1st SK construction for reconstruction
→ Can be well optimized (unified with photsensor, etc.) to minimize cost and construction work

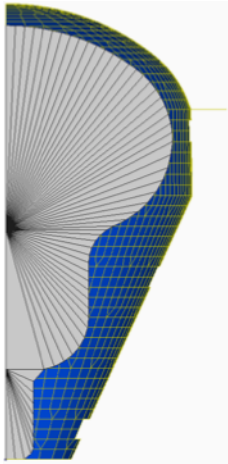
Initial case idea for HK

- Studying possibility of stainless steel and acrylic case option
  - With light mass and strong tank structure
  - For the first case study



- Asking analysis in various cases
  - Find optimum thickness of steel and acryl
  - Implosion is simulated
  - In deep water (such as 80m)
  - Accurate shape implementation and cost estimation are ongoing.
  - Might be unified with passive magnetic shield if active compensation is not sufficient.





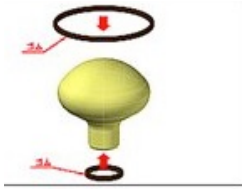
- Need many tests in high pressure with implosion later

Unified case idea with photosensor

- Bands : screws safely attached on glass for mounting
  - Materials are not good in terms of water purity
- Many steps of assembly process are required.
  - Failure or stress might be occurred during a lot of photosensor assembly by working person

Long and careful manual for each photosensor assembly

- Photosensor and case complex, assembled before delivery to HK construction site, might allow good quality control and cost reduction.
  - Case with mounting structure
  - Also work as ground shield, light shield
  - Prevent damage by external shock during construction work
  - Might be replaced with current waterproof cover

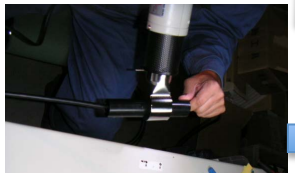


Not idea,
but concept

Cable and connector

- We have tested waterproofed HPD cable connection (for proof test) under 1-1.4 MPa water, but need more detailed study.

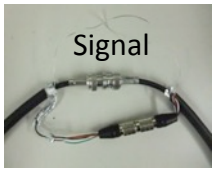
PMT
(SK)



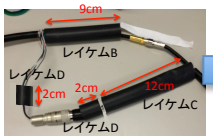
Signal line

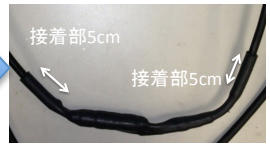
HV line

HPD
(in proof test)



Power and control lines
(No HV line)





Hard in case connection to water electronics module considered

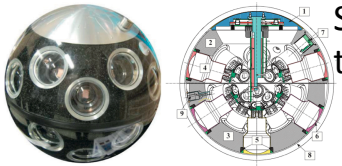
- Cable and connection capable used in high pressure water should be developed.
  - Asking companies to design and develop waterproof connector (for HPD)
- Straight wall might not require many connections other than fix or replacement, but need to establish method and technology.

Summary of photosensor option

Photosensor size (Baseline)

Size

3” Multi PMT application for deep sea ν exp.
ex.) KM3net 31 3” PMT



Sensitive to direction

NIMA695(2012)338

8” 10” 11” 12” 13” 20”

Only from HAMAMATSU
(Or LAAPD)
SK, Box&Line PMT, HPD

← Several products →

Low	Dark rate for each (by area)	High
	Installation	Hard
Many	Number of photosensors	
	Spatial resolution becomes good, would help reconstruction of momentum, PID, etc.	
	Photocoverage	Wide or equivalent Photon statistics might be good
← Different glass with low RI	RI in glass	Might decrease RI contamination in furnace →
High in design, but rate might be high in many sensors	Bearing pressure	To be measured

Total cost (?) Need cost estimation at first

- Need quick simulation to evaluate HK performance and high pressure resistance test in water

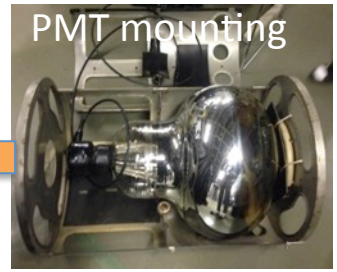
High pressure test in water

- In its design, water bearing pressure is 112m for Box&Line PMT and 250m for HPD, superior to 65m for SK PMT in stress analysis.
- Several tests are necessary to assure use in high pressure water
  - Confirm a water pressure resistance of new photosensor valve in test
    → Start as soon as possible
  - Evaluate failure rate in testing many photosensors to consider a safety factor and quality control for mass production
  - Design and test protective case to avoid a chain implosion with test
  - Quality test during production for HK
- To consider a deep water tank option for HK such as 80 or 100m, a high pressure water vessel is required.
  - Many SK PMTs were tested up to 0.65MPa 10 years ago in four tanks.
  - Reuse the tank for a quick test, and make new vessel capable to treat more high pressure water

This level was tested for B&L PMT at Hamamatsu.

Water vessel for high pressure test

- Investigated old tanks and pumps.
  - Tank and all piping seem okay to be reused around 1MPa with maintenance.
    - Asked company to rebuild test facility
  - Pump and piping are improved to pressurize water until 2MPa at least

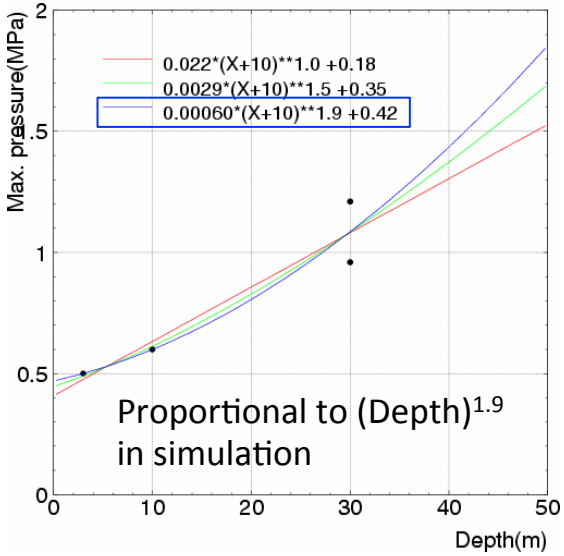


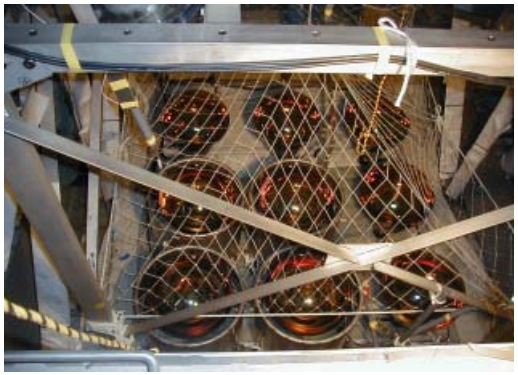
- There is a room to test PMT at Kamioka.
  - 5-10 Box&Line PMTs will be tested in March with 1MPa or more.
    - First test for HK, 7 with water proofed and 3 without electronics are available
- For a new tank with higher pressure (1.5MPa or more)
  - Test many (hundreds at first) photosensors for HK prototype test, etc.
  - Designing is ongoing, will be available in spring soon.
- This test is a key to judge the deep tank option for HK, and quick study is desired at first stage.

Implosion and test in SK

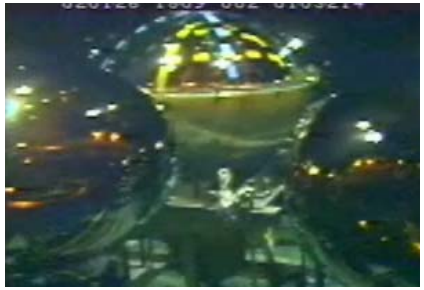
- Maximum pressure of implosion
  - drops as 1/(Propagation length) (in simple model)
  - is proportional to (Depth)$^{1.9}$
  - and to (Dia. of photosensor)$^{3/2}$ roughly
- Becomes sever in deep water, but small photosensor size and half photo coverage weaken shockwave.
- Implosion test was performed in detail in SK tank after accident.

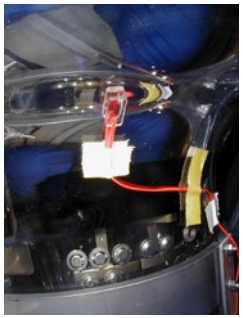
Max pressure:
HK (90m) ↔ SK x 2.5
HK (100m) ↔ SK x 3.5





Monitoring during implosion

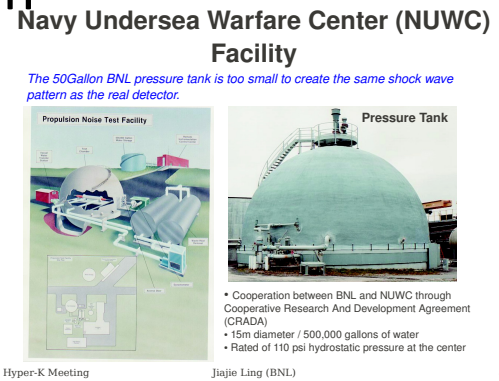


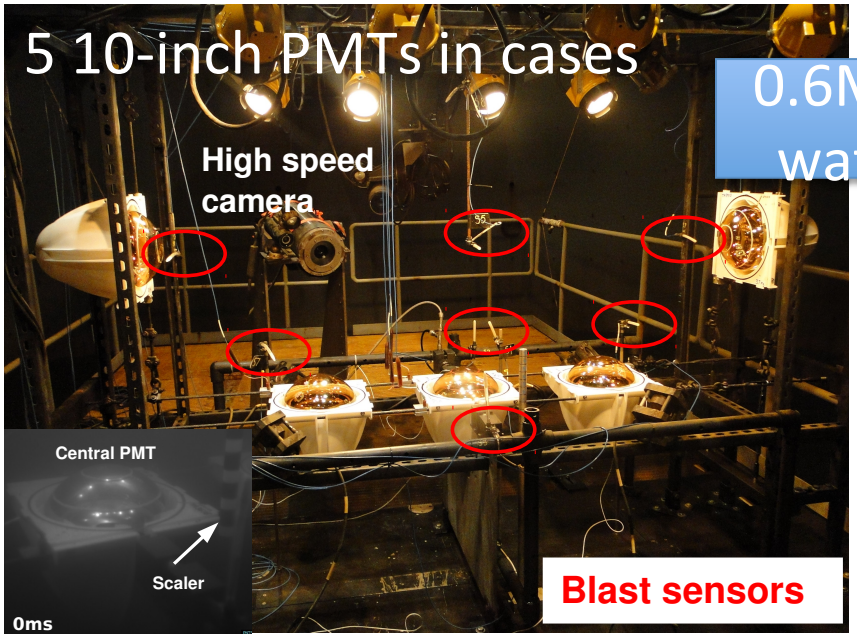


Site for implosion test

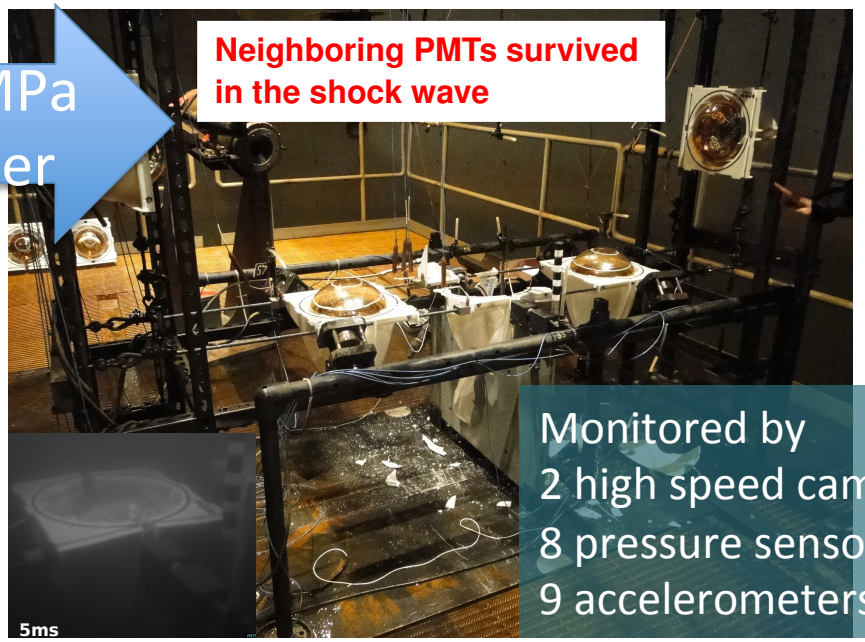
- Usually very expensive for large high pressure room
  - Confirmed around last R&D stage before production
- Difficult to find test site
  - Test in deep sea
  - Facility for deep sea research

From slides in 1st HK open meeting http://indico.ipmu.jp/indico/getFile.py/access?contribId=7&sessionId=7&resId=5&materialId=slides&confId=7





0.6MPa water



Monitored by
2 high speed cameras,
8 pressure sensors,
9 accelerometers

Notional work flow

- R&D stage

Quick test

Test several to tens photosensors to confirm actual tolerance

For Box&Line PMT, then HPD as soon as its waterproofed ver. is ready
Feedback if there are any problems occurred,

Test in high pressure water

For a few month, at least by next summer

Test around 2MPa

Determine HK design

Mass test

Around 2016-2017, as in factory

Test around 200 photosensors for HK prototype,
and all after production as quality check
in order to evaluate failure rate

Test with case R&D

Case is optimized

Implosion test

Test final design before production
with protective case

- Production stage

Quality test

Test all or sampling photosensors (depending on discussion)
after production

Conclusion

- New 50cm PMTs have nice high pressure tolerance in design, but it should be confirmed.
  - Deeper tank option might be possible depending on more studies with test.
  - As well as all related accessories (case, cable, connector, etc.)
- Need to list possible options with cost estimate.
  - Bearing pressure will be confirmed in test for a few months.
  - Performance should be evaluated in each option.
- Preparation is going on for new photosensor test soon from March, and conclude each possibility in deep tank option ASAP.