Mechanical design and system integration：HK

Workshop on the evolution of advanced electronics and instrumentation for Water Cherenkov experiments

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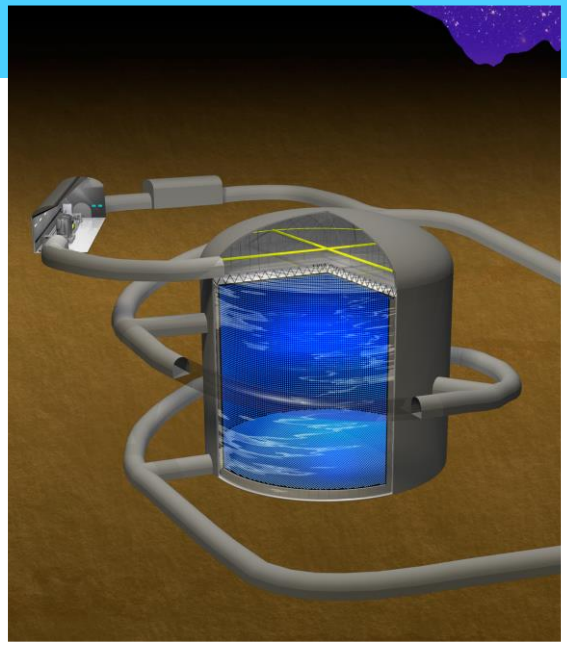
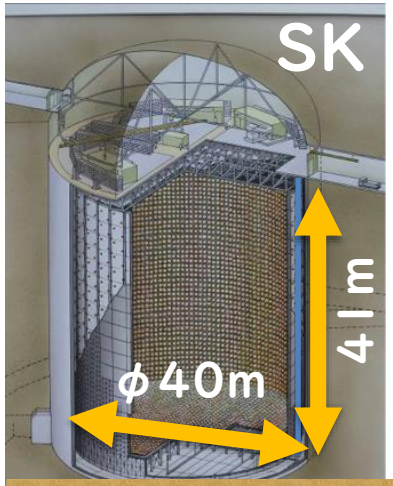
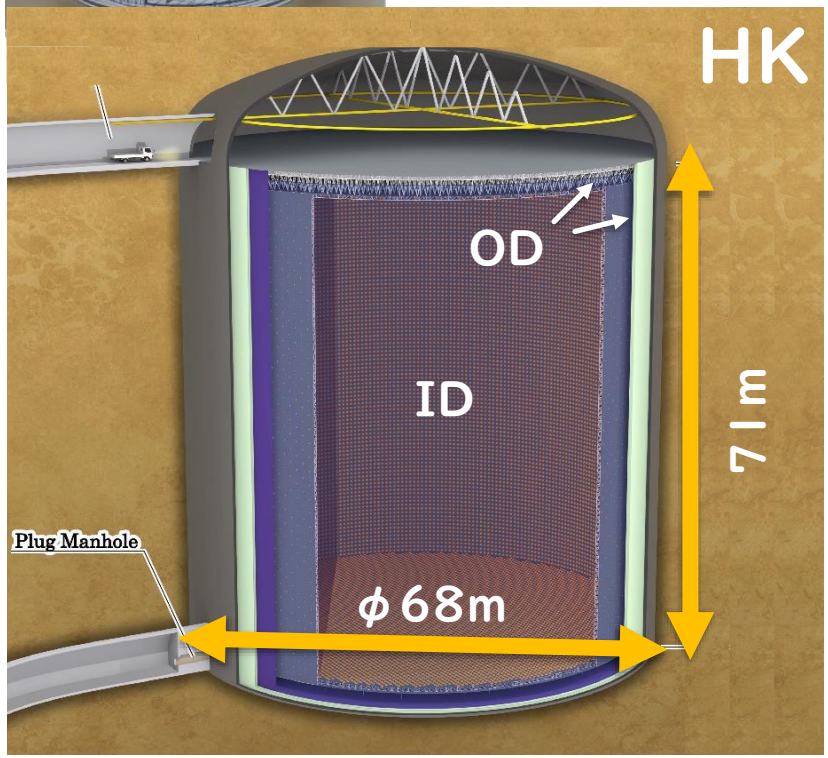


Hyper-Kamiokande

Hyper-Kamiokande Detector



2nd to 3rd Gen.



	Super-K		Hyper-K
Depth	1000m		650m
Volume (k-ton)			
ID + OD	50.0		258
ID	32.5		217
Fiducial	22.5	x8.3	188
# Photo Sensors			
ID 50cm PMT	11k		20k ~ 40k
ID multi-PMT		new	φ50cm ~1.3k
OD PMT	φ20cm~1.9k		φ3" ~8.5k

ID 50cm PMT

ID multi-PMT

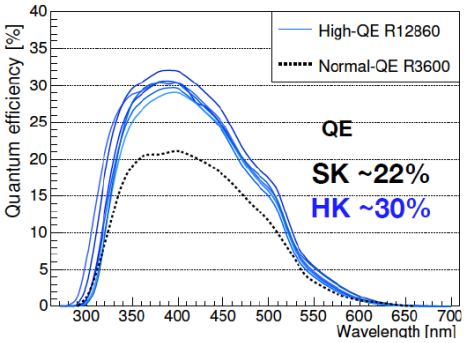
OD 3" PMT w/ WLS

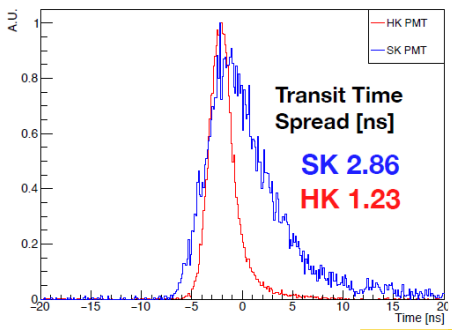
ID 50cm B&L PMT

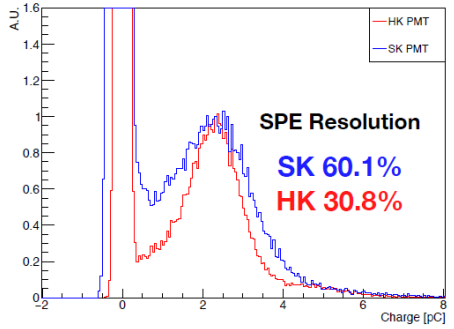
used in SK ~2019

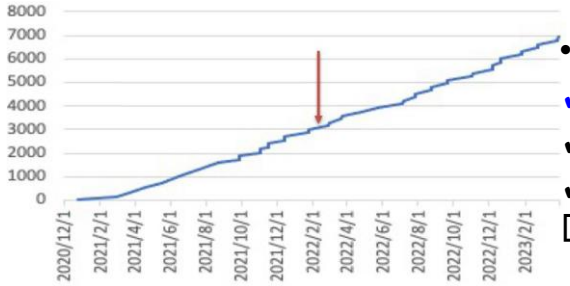
Box & Line PMT : new high performance PMT

- (Q.E.+C.E), Time Res., SPE P/V ratio = x2 of SK
- Low dark rate = 4kHz = ~SK ⇒ LowE sensitivity









- 300PMT delivery/month

✓ ~3300PMT by Mar. on schedule

✓ 100% inspection for initial 700PMT

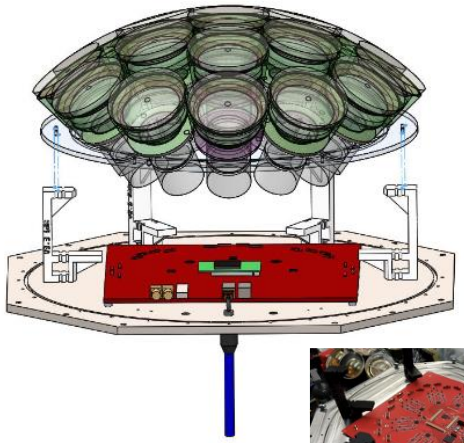
✓ 10% inspection after that

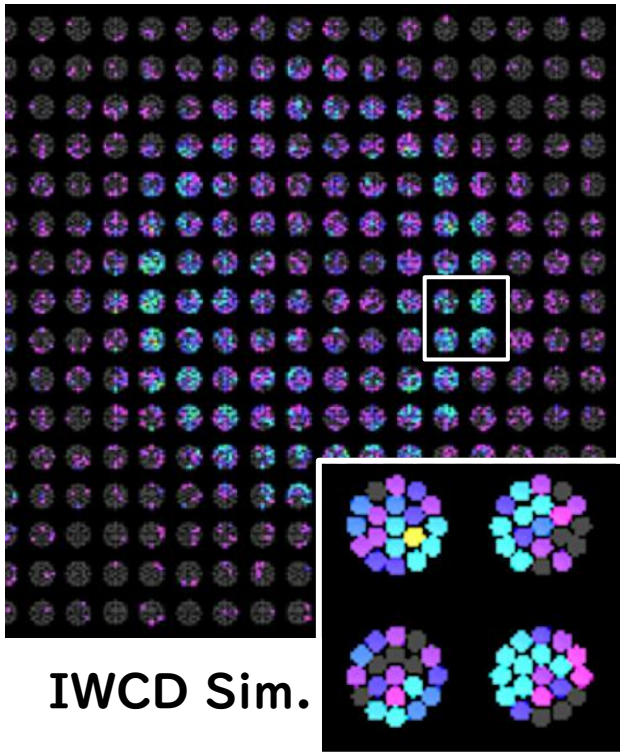
☐ Long-term performance test on going

- Chain Implosion Prevention by
  - Acrylic Cover
  - SS Cover

☐ Under Evaluation

ID multi-PMT : mPMT





IWCD Sim.

50cmϕ mPMT

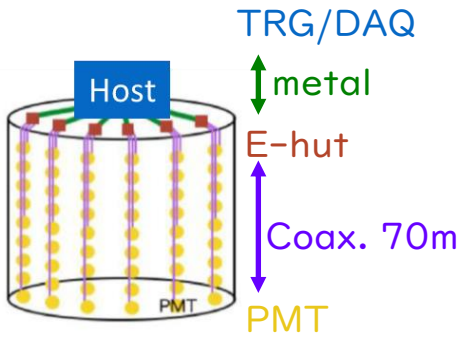
- 19x3” PMTs : x2 time resolution to 50cm PMT
- Sensitivity for incident angle
- Calibration of 50cm PMT
  ⇒ Reduction of Syst. Error even w/ less PMTs.

High event reconstruction w/ 50cm PMT

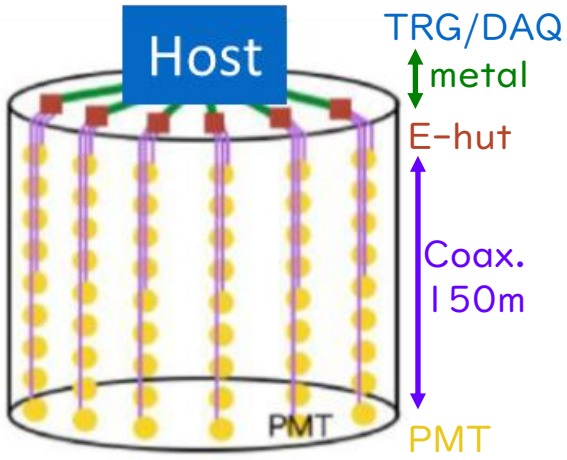
- Separation of multi-ring event
  ⇒ Proton-decay, neutrino oscillation
- BG reduction near detector wall
  ⇒ Larger statistic w/ larger FV

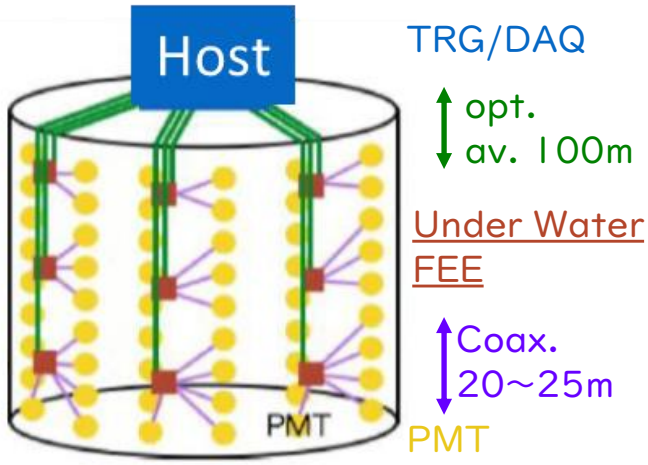
DAQ/FE electronics Topology

DAQ Connection



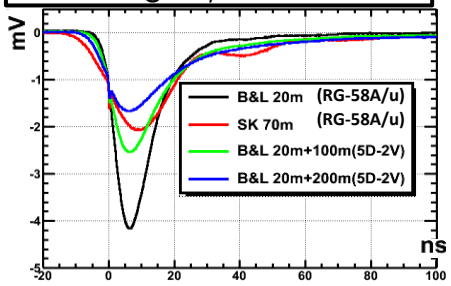
SK:40mϕx40m





HK68mϕx71m

PMT sig. w/ diff. coax.



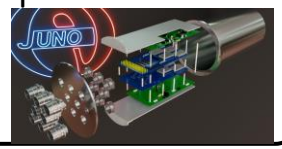
(just) Longer Coax.
- worse discrimination
- worse time resolution

⇒ Thicker & Longer Coax. ?

Merit = RG58 can be adapted for shorter coax cable
- → Good balance of cost
- → Smaller volume & mass of cables
- → Maximized detector volume

Challenge = 10 years un-replaceable condition during DAQ
each components are required to have <0.1%/year failure rate

Difference of underwater components (to KM3Net, IceCube, etc)
- Shallower, but not so ⇒ customized low-cost components
- Much more channels ⇒ JUNO-SPMT is our *Gigantum*



Baseline Idea of Underwater Connection

Fiber Optics + Metal
(Communication, LV-Power)

Electronics Hut

Feedthrough

ID50cm Only Underwater Vessel

~250

Feedthrough

2m

Underwater Connector

20m

RG58+RG174 x 24
(SIG, HV)

~20k ID 50cm PMT

Feedthrough

ID50cm + OD Underwater Vessel

~700

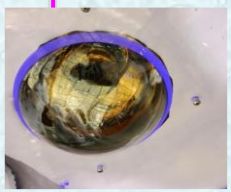
x20

Feedthrough

2m

Underwater Connector

RG58x12
(SIG+HV)



~8k OD PMT

Feedthrough

ID mPMT Concentrator Box

~100

FT

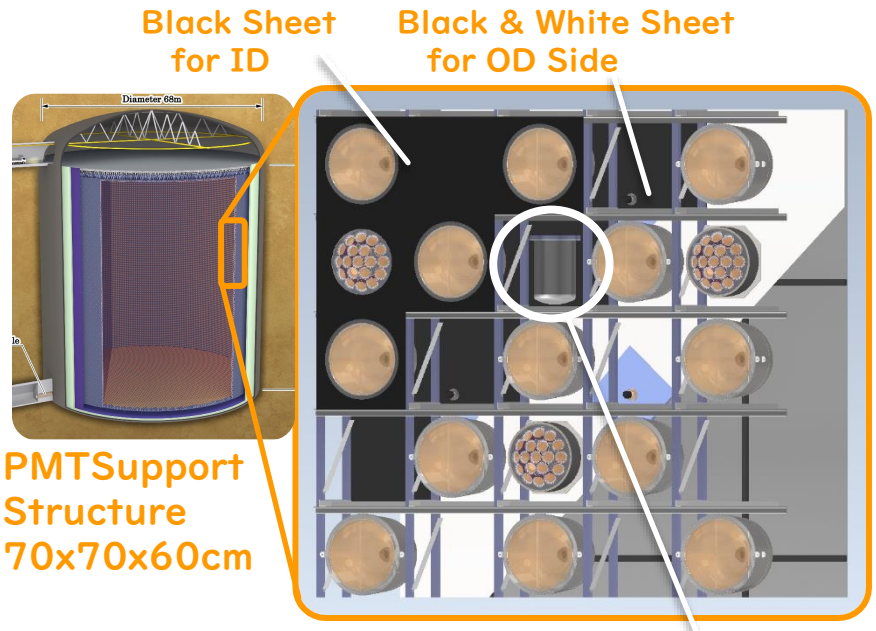
Underwater Connector

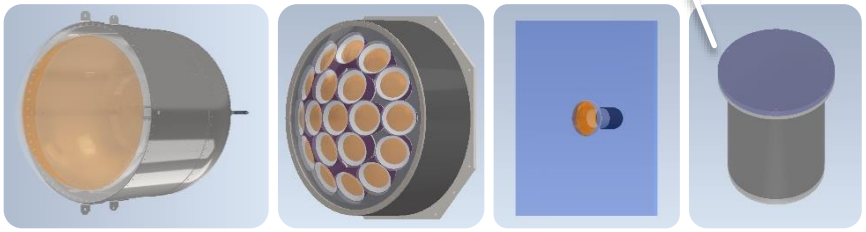
Ethernet x12
(SIG, LV)

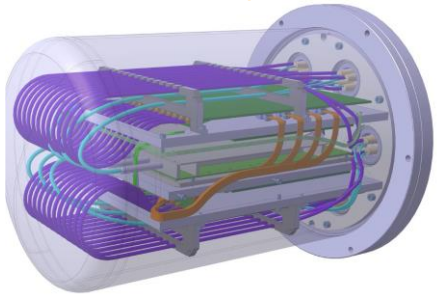
FT

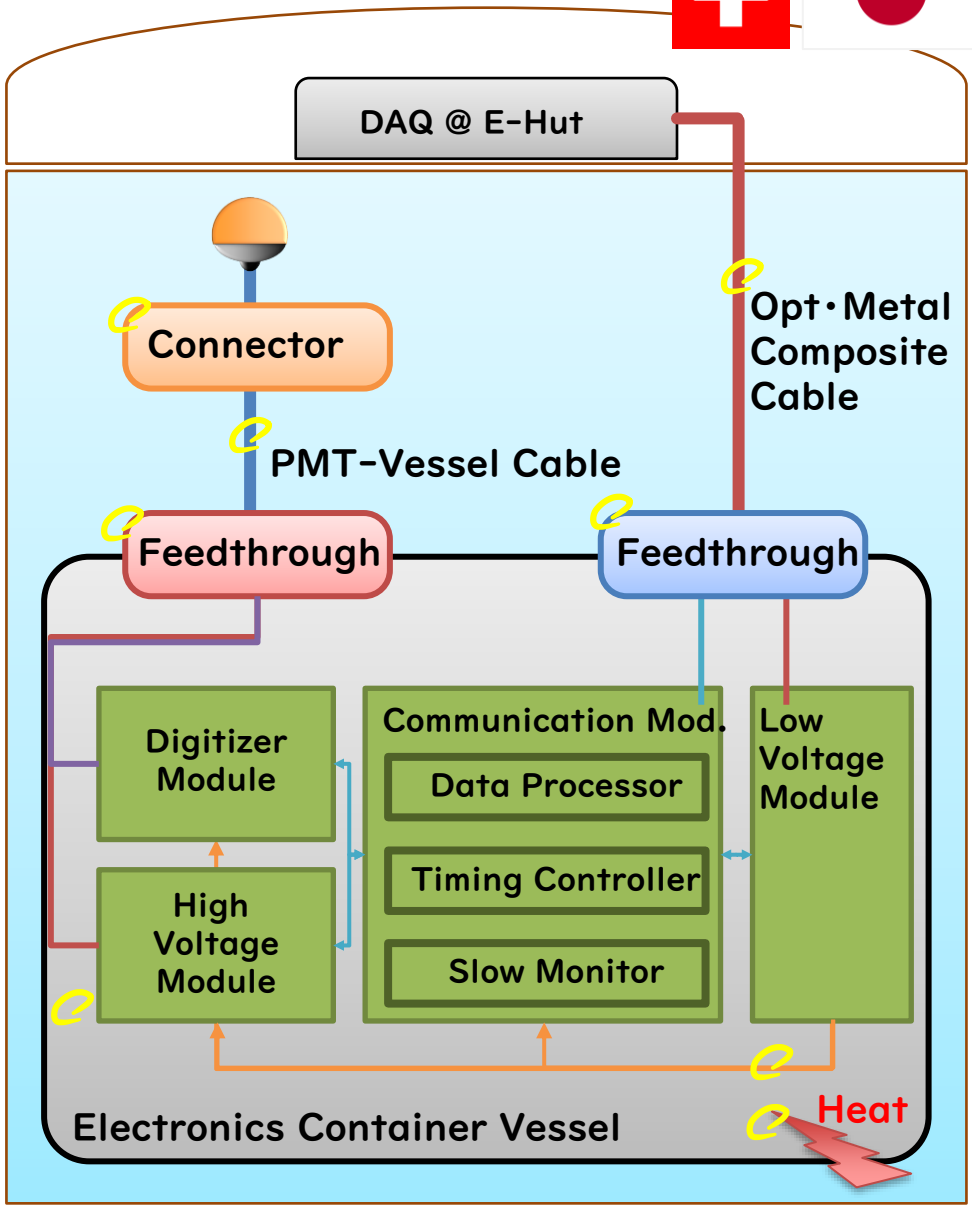
~1.3k ID mPMT

ID50cm (+OD) PMT Underwater Vessel

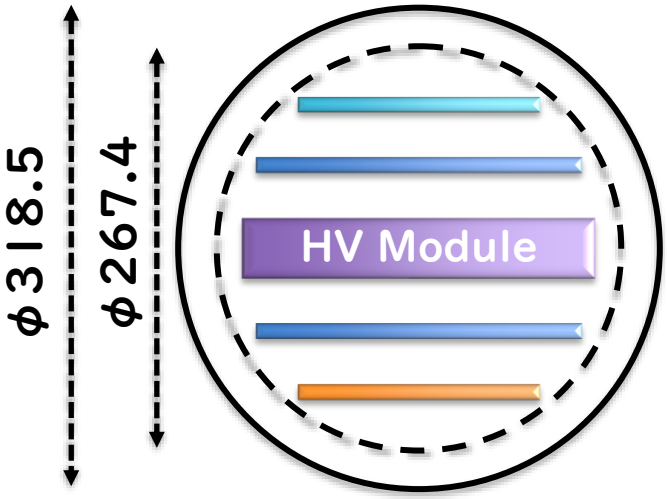








Underwater Electronics Containing Vessel



- Communication Module: 200x200mm
- Digitizer Modules: 210x300mm
- HV Module: EuroCard 6U (233) x300mm
- Low Voltage Module : 200x200mm

Vessel needs to contain
5 PCBs of 230x300mm
Considering Cabling, 300mmϕx400mm

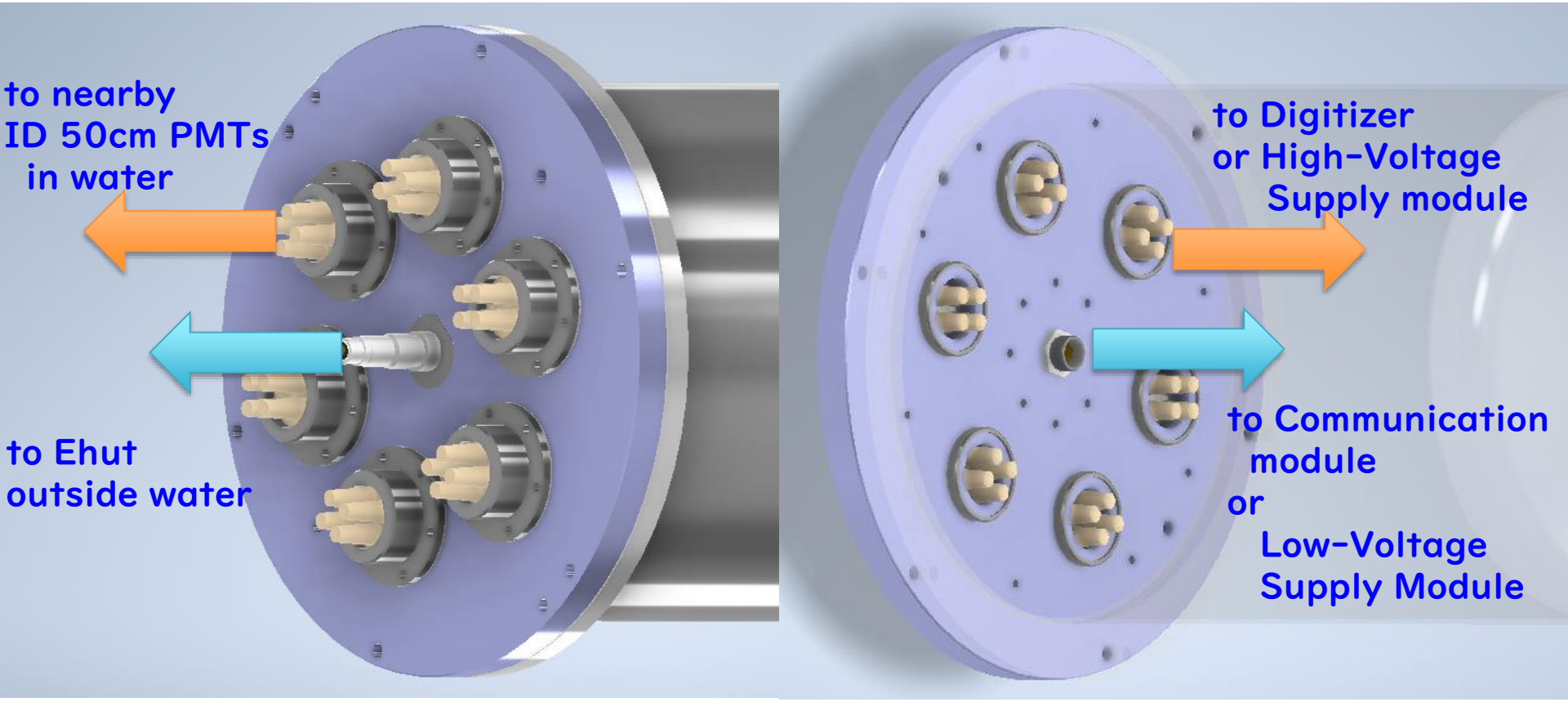
1st Idea

- SUS304
- ~48kg
- Larger Safe Factor
- Pressure-proof
  - ✓Double O-rings
  - ✓10+bar & 1 month

2nd Idea

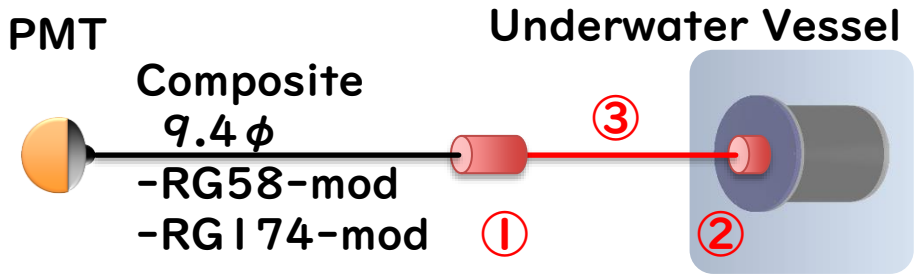
- SUS316L
- ~31kg
- Lighter to seek handiness and cost effectiveness
- Pressure-proof
  - ✓Double O-rings
  - ✓10 bar & 2 days

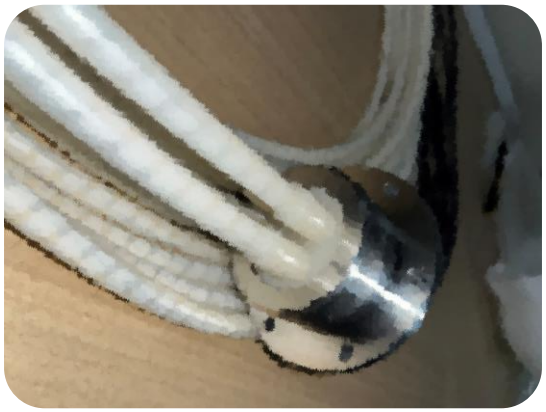
Cable Entry Flange



- PMT cables : x24 (RG58-mod, RG174-mod)
  (Signal , HV)
- Communication Cable : x1 (12-FO, 2-metal)
  (Data, LV Power)

PMT Cable Feedthrough (ID 50cm)



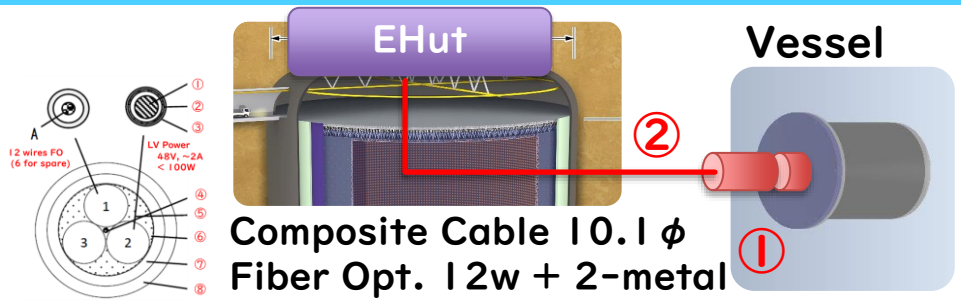


Characteristics

- Connection
  - Underwater Connector ①
    - Connection btw. PMT & Vessel
      for ease of connection works for 24 cables
  - 4ch Panel Mount Feedthrough ②
    - Reduction of connection
      for better waterproof and connection work
- Waterproof
  - Waterproof Cable ③
    - Water-blocking filler
  - Double O-rings for each connection
- Electrical
  - HV-tolerance enhanced cables and connectors
- Environmental Compatibility to UPW
  - Polyethylene, SS316, FKM, Silicone

- Validation : On-going
  - ☐ Checking ease of connection
  - ☐ waterproof of feedthrough @ 10bar
  - ☑ waterproof of cable @ 10bar △
    water-blocking is confirmed,
    and trying to enhancing..
  - ☑ short HV tolerance : 3.3kVdc 1000sec ○
  - ☐ long HV tolerance : 3.3kVdc 1month
  - ☐ RF characteristics
  - ☑ soak test : some had elution, replacing.. △
  - ☑ cable radon emanation : ~PMT cable ○
  - ☐ cable gas permeation

Communication + Power Cable Assembly

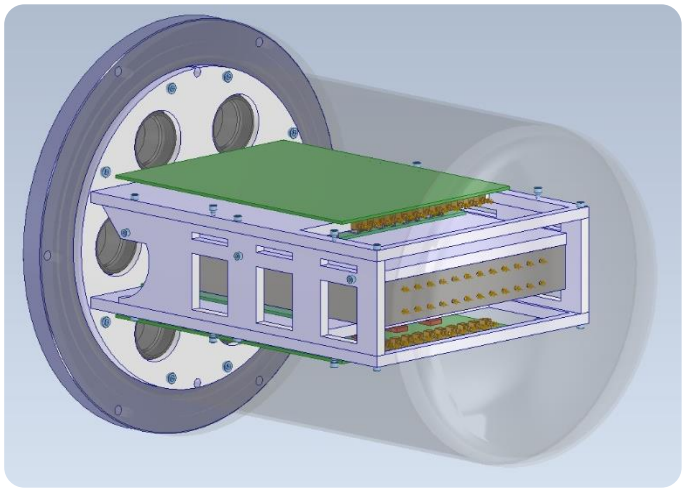


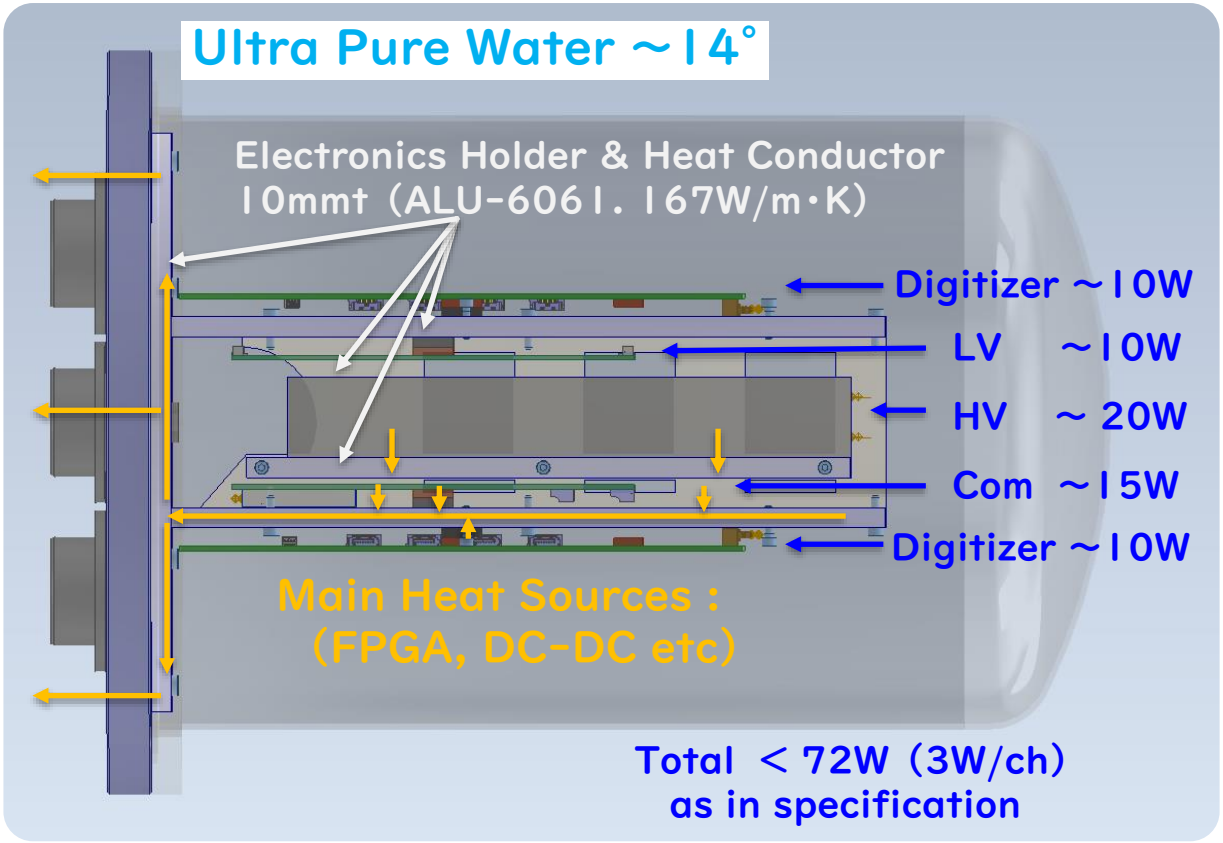
Characteristics

- Connection
  - Panel Mount Connector ①
    - Connection btw. EHut & Vessel for only 1 cable.
    - Cost reduction by component reduction
  - Composite Cable + Plug ②
- Waterproof
  - Double water-block component for each connection
  - 12bar waterproof
- Electrical
  - Low reflection loss fiber
- Environmental Compatibility to UPW
  - SUS316, FKM

- Validation : On-going
  - ☑ Checking ease of connection
  - ☑ waterproof of feedthrough @ 12bar ⇒O 1.5MPa
  - ☑ reflection loss
    - ☑ before connector assembly ⇒O~SPC
    - ☑ before connector assembly⇒△~FC
    - ☑ BERT
    - ☐ Jitter
  - ☐ insertion loss
  - ☐ insertion loss at 10bar
  - ☐ soak Test
  - ☐ cable Radon Emanation
  - ☐ cable Gas Permeation

Electronics Holder & Heat Dissipation Design



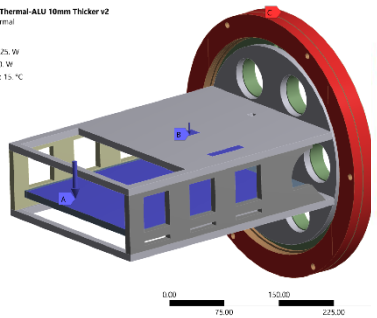


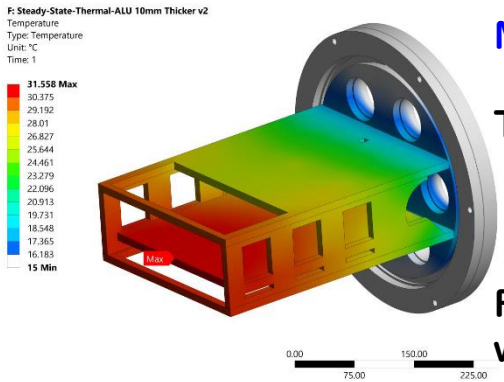
Total < 72W (3W/ch)
as in specification

Steady heat conduction analysis

- Lid outside : 15℃
- Heat on HV : 25W
- Heat other : 50W

total :75W



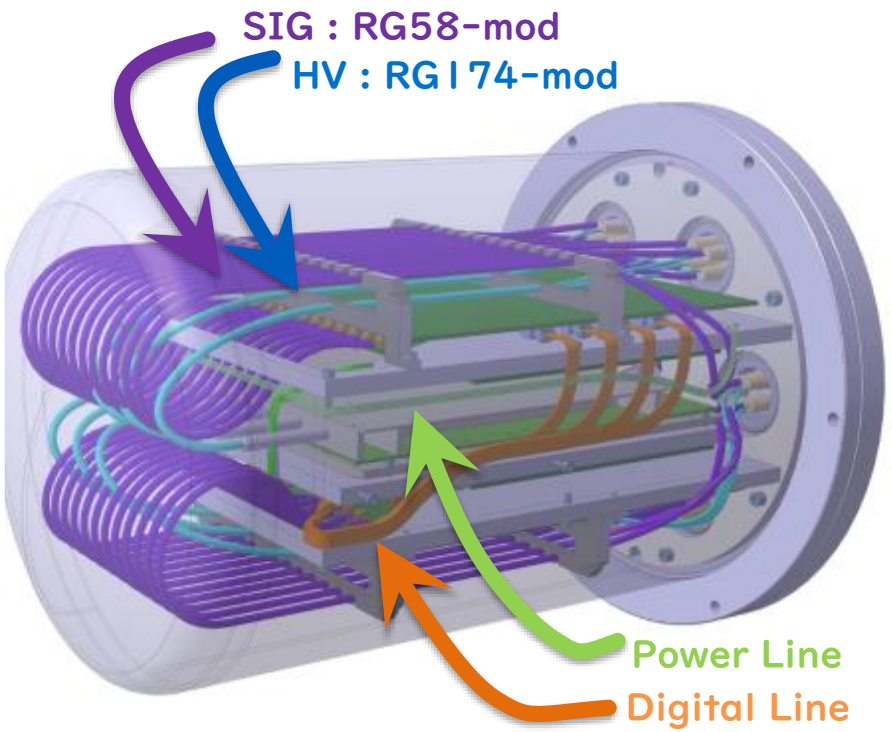


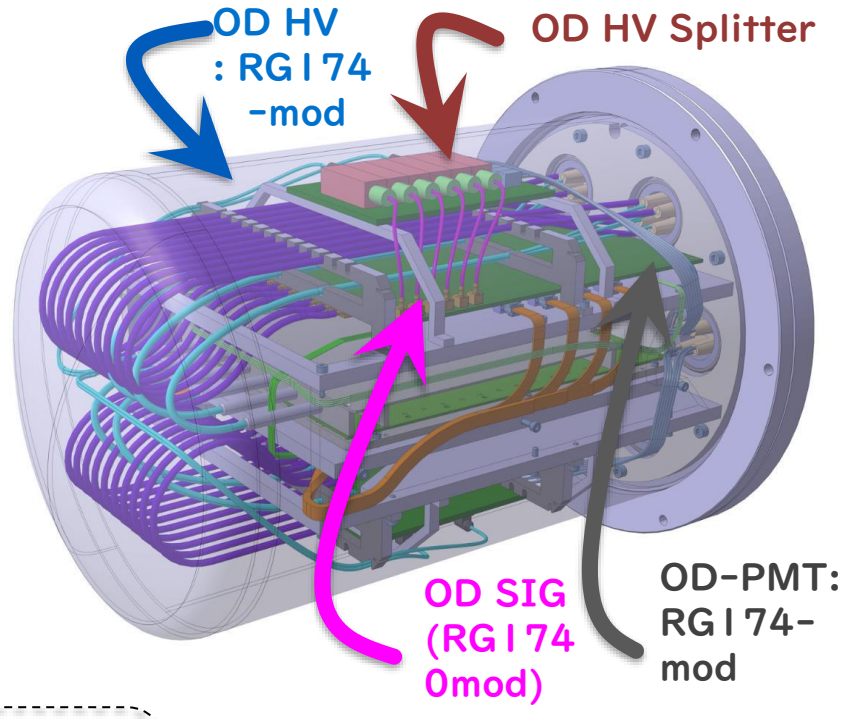
Max. Temp @ Holder = 31.6℃

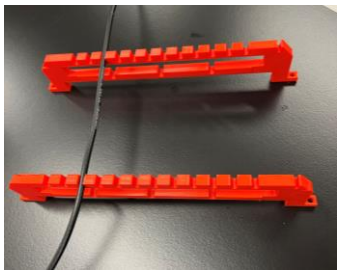
Temperature for FIT
Chip : 45℃
Ambient : 25℃ seems possible.

Realistic test with Dummy PCB with heat sources is planned.

Electronics Holder & Cabling (+OD PMT)

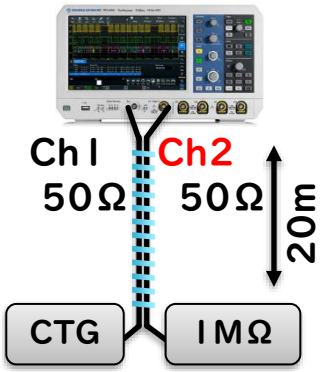


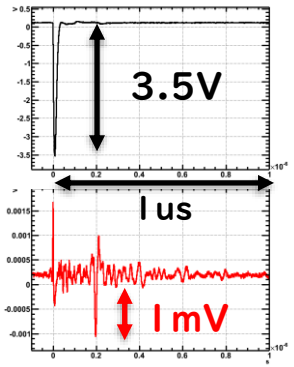




☑ Cable Guide
to keep distance btw RG58 to suppress cross-talk

Cross-Talk
btw RG58





c.f. 1mV=
disc. threshold

☑ power/digital lines are put away from Coax.
☑ reflected on PCB design.

☐ assembly test with dummy PCBs
☐ EMC and cross-talk check by integration test

Summary

- Hyper-Kamiokande Experiment decided to utilize
  - FE electronics near PMT at most 71m-deep ultra-pure water
  - Underwater electronics container

- Underwater component consists
  - Electronics Containing Vessel
  - PMT cable feedthrough assembly
  - Communication cable connector assembly
  - Related design including heat dissipation, cabling

- Milestones of R&D
  - '22-2Q : Component R&D results & collaboration review
  - - : Integration Test
  - '24-2Q : Start mass production
  - '25-4Q : Start Installation
  - '27-3Q : Start Observation

- Installation design is also considered
  - 4-fold interleaving connection to minimize continuous dead channels in case a vessel failure as a baseline design.