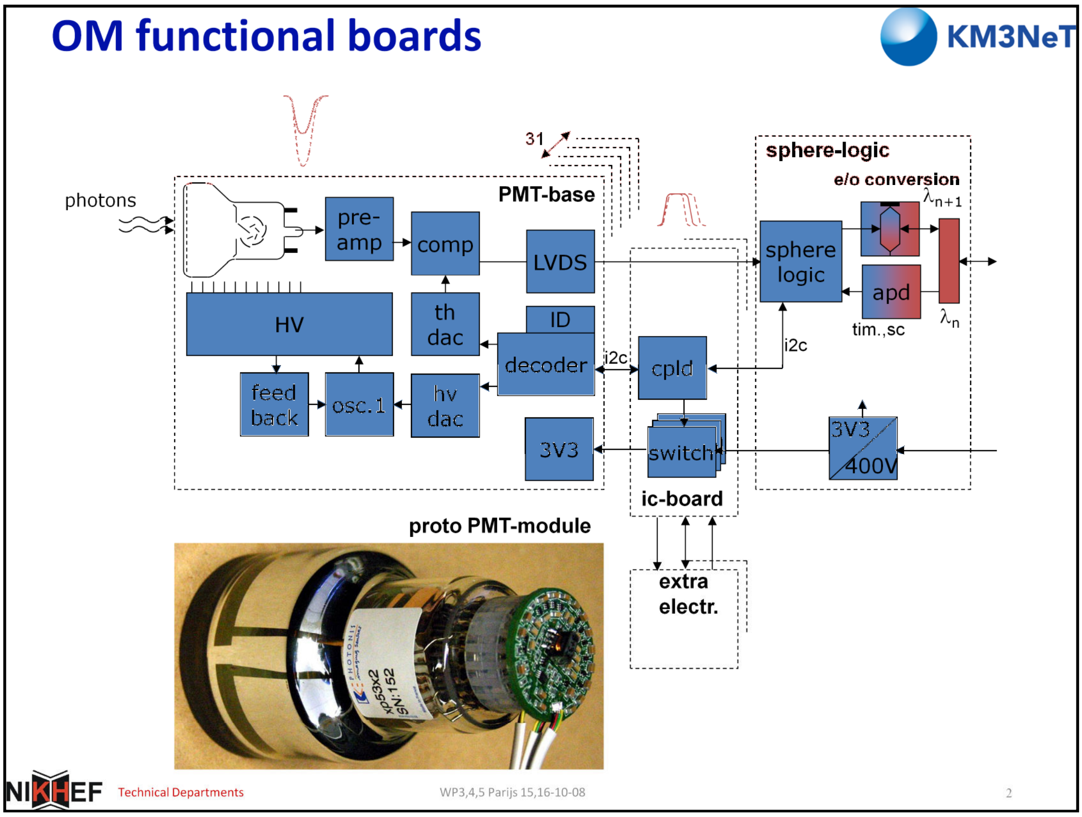
KM3NeT

Status of the Multi PMT Optical Module development

Contribution to WP3,4,5 meeting Paris

15 + 16 September 2008

E. Heine



In terms of a floor, like Antares or NEMO, the left hand side can be considered to be the OM part and the right hand side the floor logic part.

On the ic-boards extra I/O is available for extra functions like compass, tilt, acoustic, etc. if fitting in the power budget and if fitting in the I?O constrains (I2C).

PMT-base <30mW guess (31* = 930mW)

Ic-board <200mW guess (2* =400mW) + the load of extra electronics.

Sphere-logic <4W guess

Total budget <10W guess, dictated by thermal behavior.

Extra electronics can be:
-compass (f.i. HMC6352 of Honeywell or http://www.magneticsensors.com/datasheets/HMC5843.pdf)
-tilt measurements
-acoustic system

These electronics has to fit to a PMT I/O port of the ic-board:

3.3V, <100mA, i2c communication, fast output, total power <4.5W

Purpose of the ic-board;

-To complete all the wires / halve sphere to ease the assembly procedure

-To minimize the PMT-base electronics and so the base dissipation and the cabling.

Multi PMT OM

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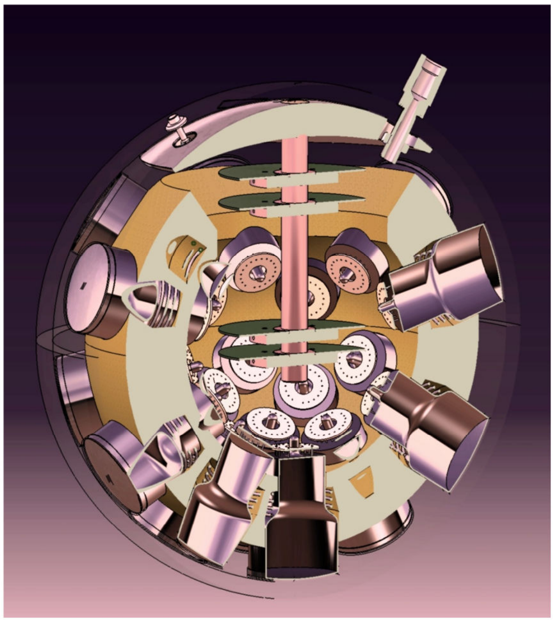

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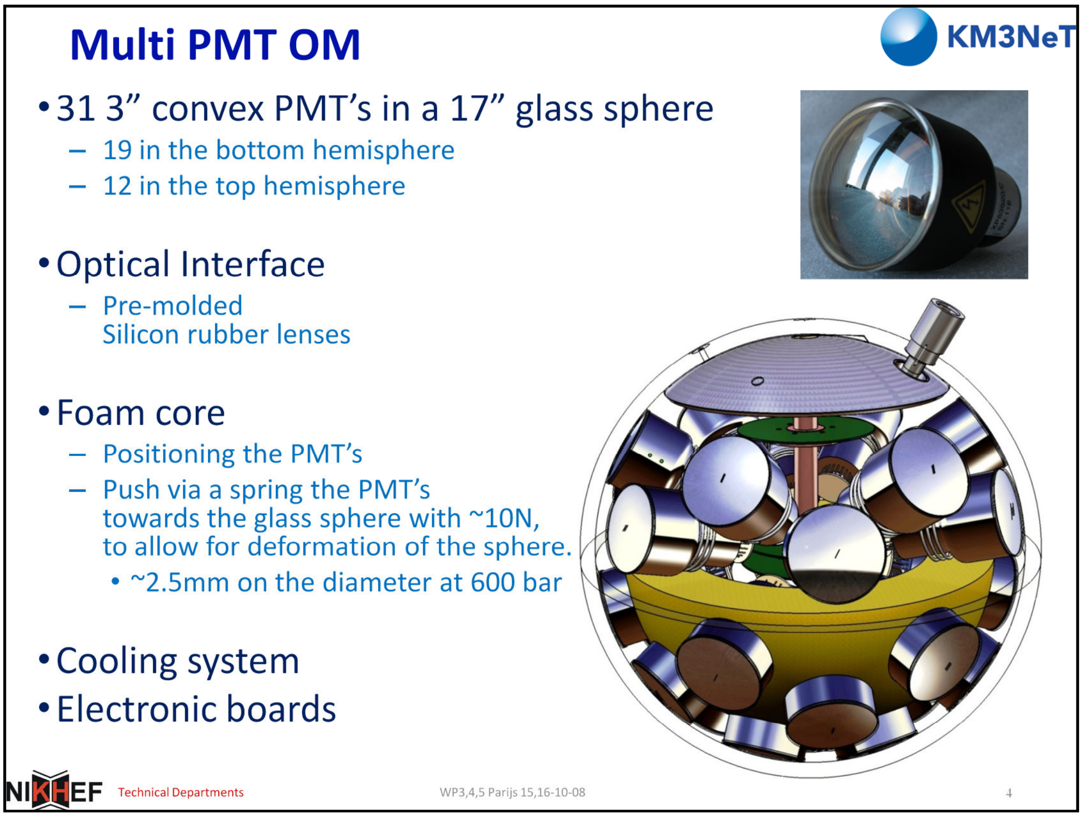
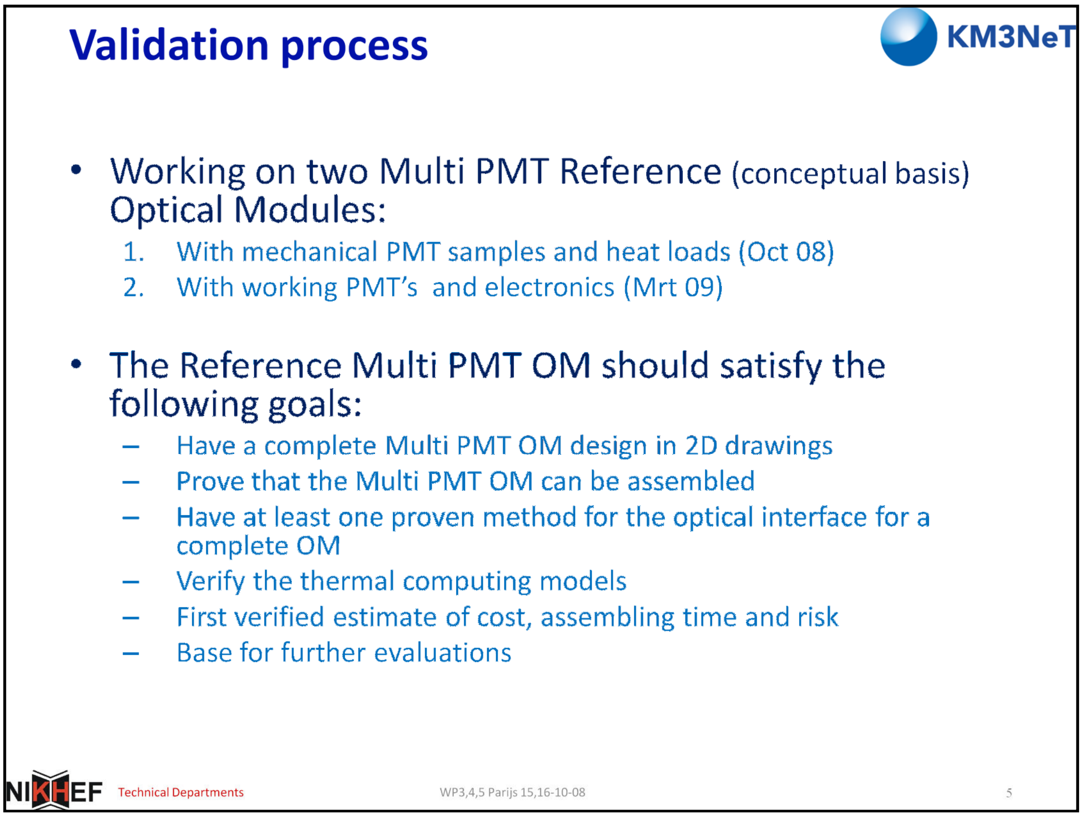
3D artist vision.

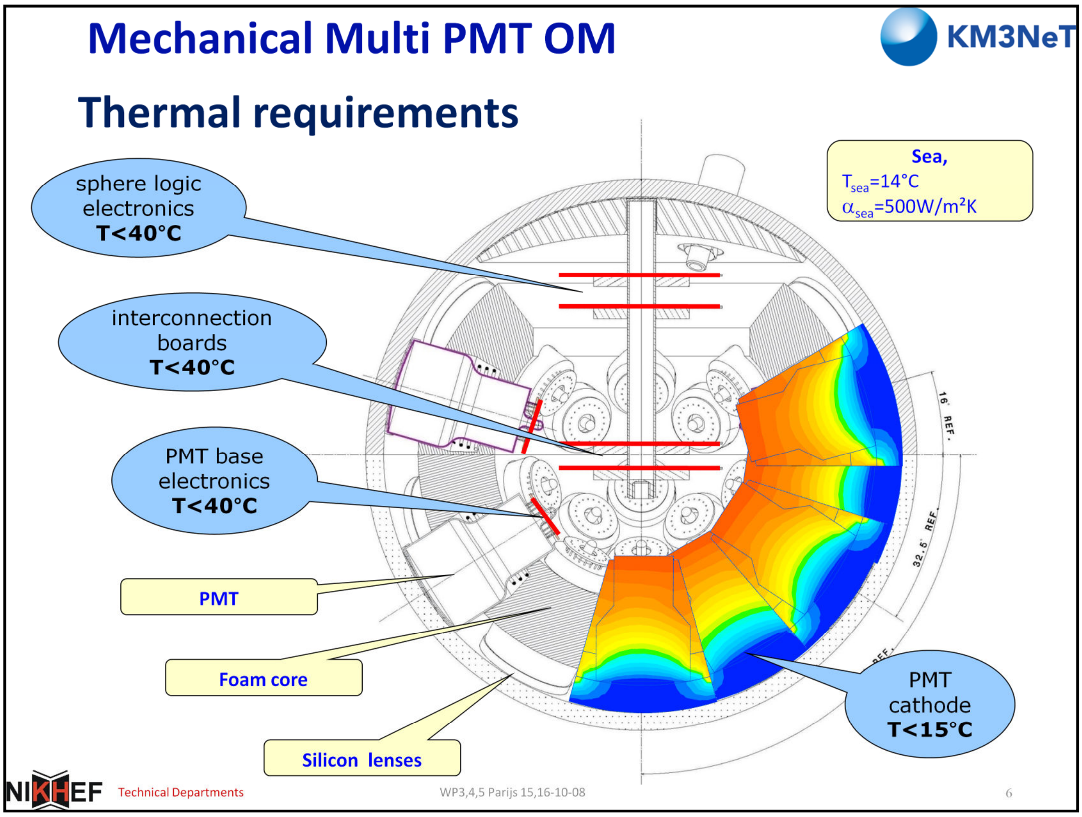
A lot of items has to be optimized. Therefore a reference module is built.



The tube; XP53b2 of Photonis.
A research trajectory to optimize the tube for this project under a non-disclosure contact with Photonis.
A 17” sphere of Nautilus can withstand the pressure with a reasonable thickness (optical properties).



The first reference module is meant to verify the computing models to calculate the thermal effects and checking the handling of the assembling steps.

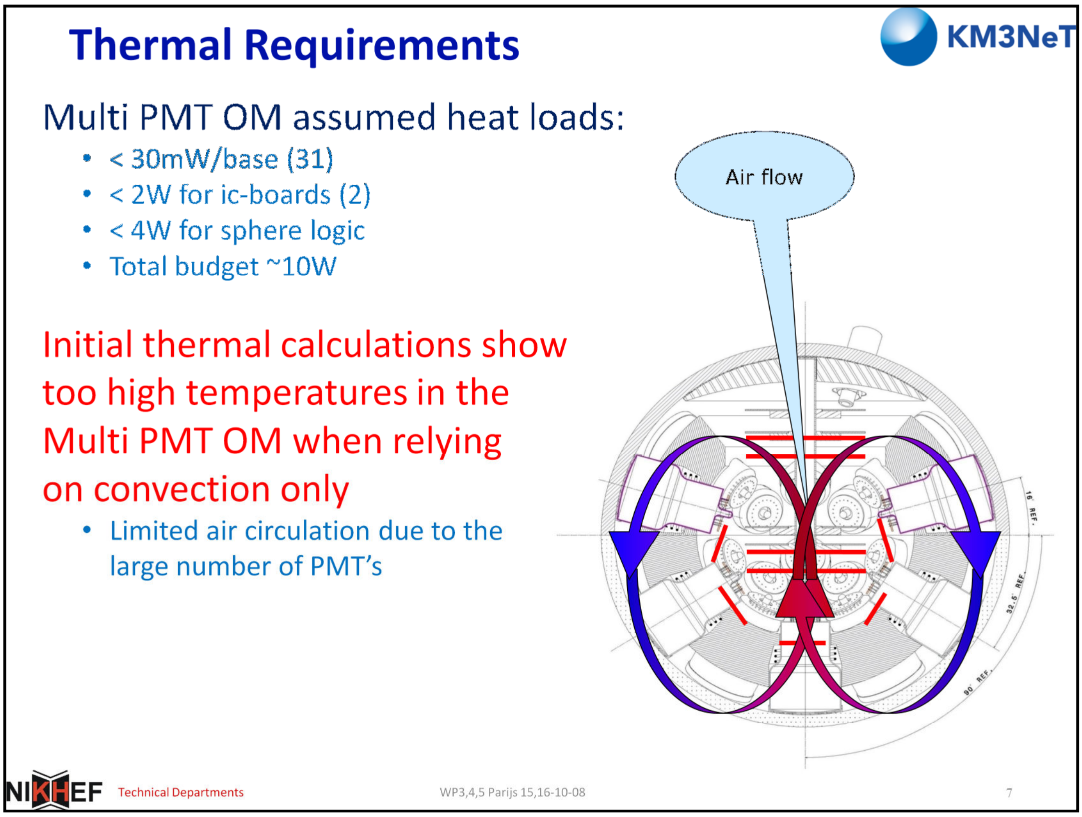


There are some arguments to keep the temperature low as possible;

-Temperature has a major impact on the lifetime.
By the rule of Arrhenius each 8-10°C means a factor 2.

-Solder with lead free solder gives a higher chance on more and longer tin whiskers, according the experiences at NASA Space-station.

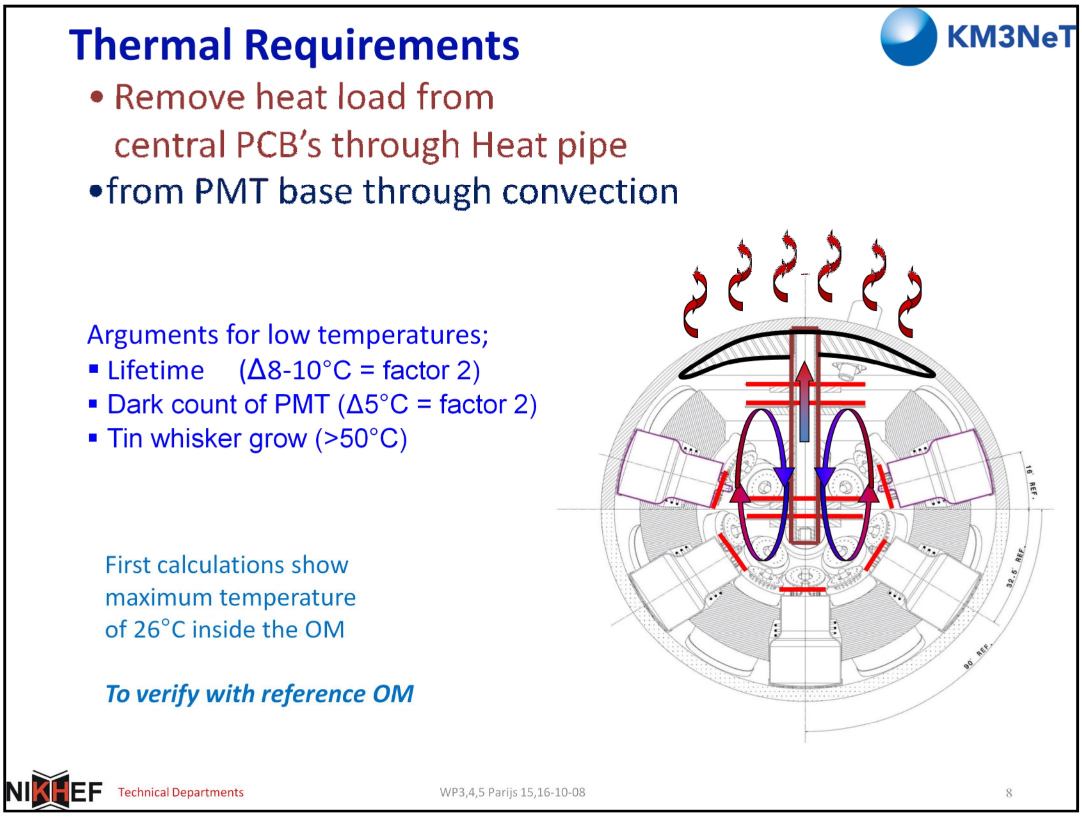
-Low temperature for the PMTs means low dark count rates. Each 5°C a factor of 2.



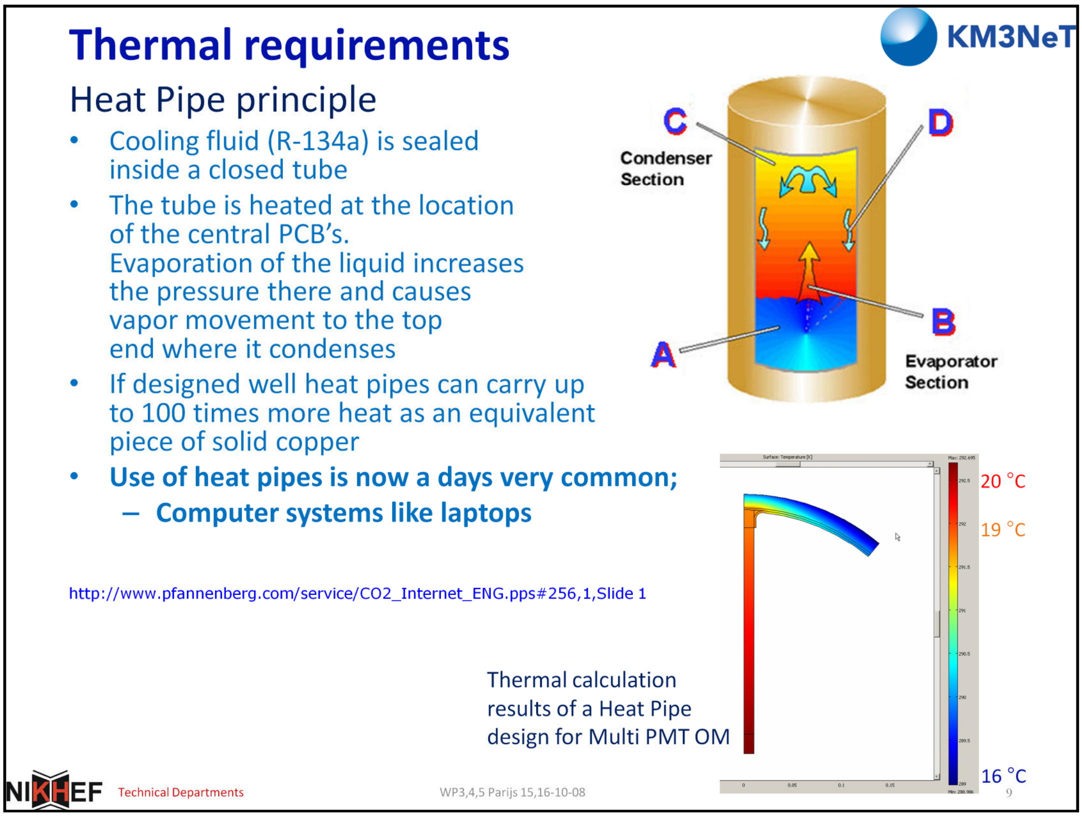
Calculated temperatures up to 80°C.

Supposed airflow flows between glass and foam with holes in lower foam as retour.

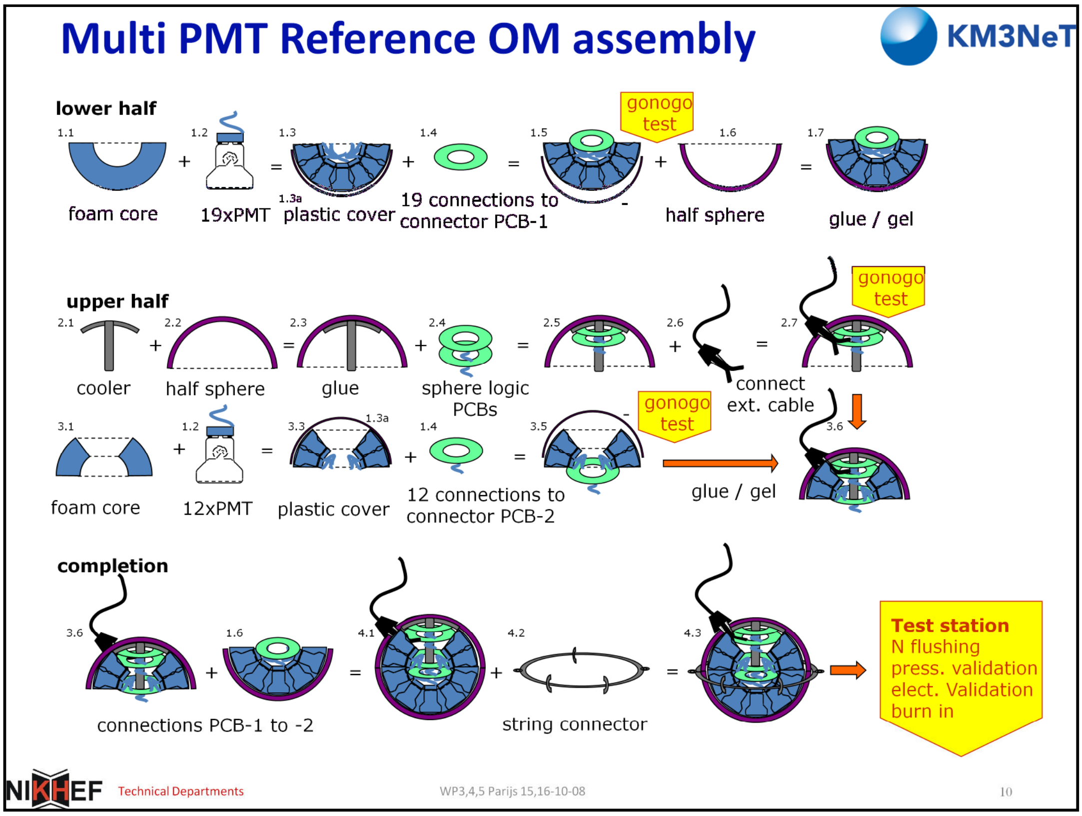
In the center space of the sphere there are a lot of wires to connect the PMTs, so there is hardly space for an airflow.



Calculation outcomes are conform equivalent test results of Saclay, presented in Genoa and Amsterdam. Next step will be to proven it in a reference model.



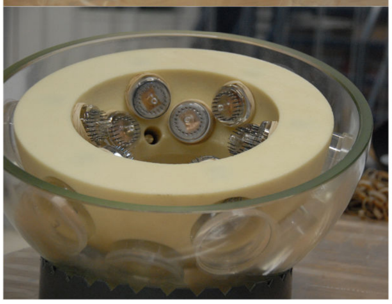
tetrafluoroethane (R-134a) is an inert gas used primarily as a "high temperature" refrigerant for domestic refrigeration. It has no ozone depletion potential. It is also used to cool computers. It will banned from 2011 in the EU, due to there global heating potential (1300). A possible replacement will be CO2 (global heating potential = 1).



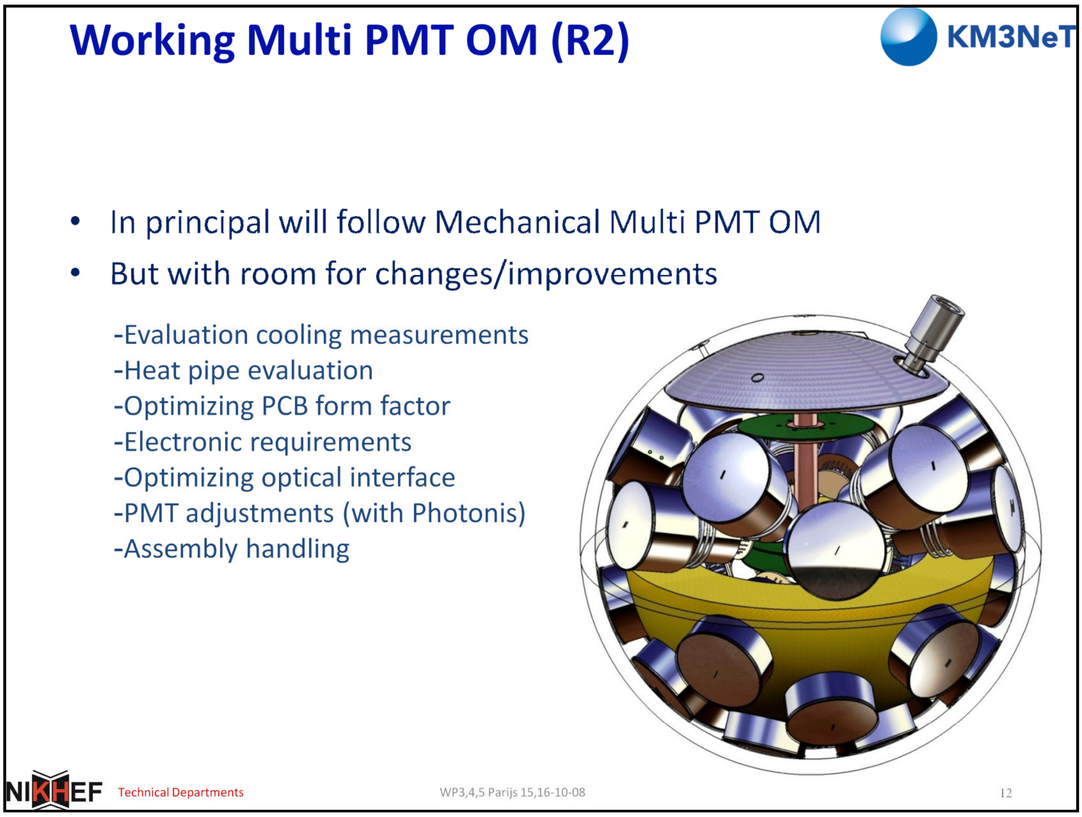
1.1 foam core with holes for PMTs for the lower half, i.e. 19 holes.
1.2 PMT assembly with base electronics with test report. Assembled and tested by PMT producer?
1.3 core with PMTs. PMTs temporarily fixed to the core with temp. plastic outer shell (1.3a) (protection too).
1.4 interconnection board (ic-pcb); (3V3 switch, slow control-1 wire Dallas prot., lvds outp)/pmt, 1*data+19lvds to next board
1.5 connection to ic-pcb and tested (special test device, just go/nogo tests)
1.6 glass sphere without any hole
1.7 1.5 glued into 1.7 (or alternatives to gluing), store to the next step 4.1
2.1 aluminum cooler, with heat pipe like stem
2.2 upper sphere with 2 holes (resp. connection and flushing)
2.3 cooler glued with heat conducting glue to the sphere to adapt dimension changes of sphere by high pressure
2.4 sphere logic boards (e/o converter, data compile logic, etc.)
2.5 2.4 thermal mounted on 2.3
2.6 external connection cable with connector to breakout box of the vertical string and special penetrator to the sphere.
2.7 connect the wires and splice the fiber to the sphere electronics. Keep the penetrator insert clean and push careful. Store to the next step 3.6
3.1 foam core with holes for PMTs for the upper half, i.e. 12 holes and a free sector of 80°.
3.2=1.2 PMT assembly with base electronics with test report. Assembled and tested by PMT producer?
3.3 core with PMTs. PMTs temporarily fixed to the core with plastic outer shell (1.3a)
1.4 interconnection board; (3V3 switch, slow control, lvds outp)/pmt, 1*data+19lvds to next board (7 channels used for general purpose)
3.5 connection to ic-pcb and tested (go/nogo tests with device from 1.5).
3.6 3.5 glued into 2.7 (or alternatives to gluing), store to the next step 4.1
4.1 assemble 1.7 and 3.6, connect the ic-pcb of 1.7 careful (less space!) thermal and wires to 3.6.
4.2 external ring device to mount the complete sphere to the vertical strength lines.
4.3 The complete device can be lined out in a vacuum chamber

Progress

Upper hemisphere with 12 PMTs (mechanical samples), Pressure measurement



Lower hemisphere with 19 PMTs.



Next steps.

-Improvement of the PCB - heat pipe interfacing

-Improvement of PCB to PCB connections (solid state)

--Sphere logic boards in a halve moon model connected to the square heat pipe gives better cooling

--IC-boards flat against the heat pipe and hard connected to the central boards are easier to mount when both halve spheres are integrated.

-Improvement of the optical interface production

-Optimization of the heat pipe

--square cross section easier to make contact with the PCBs for cooling

Vertical structure e/o cable

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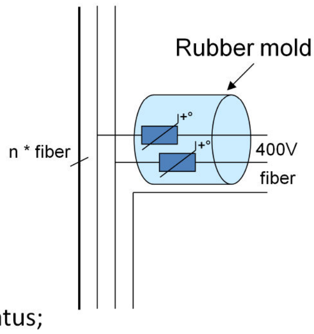
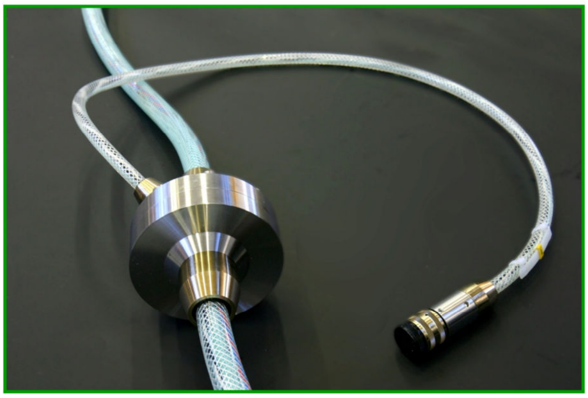
In co-operation with Seacon®

Future;
1* fiber / OM
2* Cu wires 400V with fuses / OM output





Status;

- Plans for integration of fuses
- Preparing 2e series pressure tests at NIOZ
- Evaluating material, form factor
- Preparing vertical test

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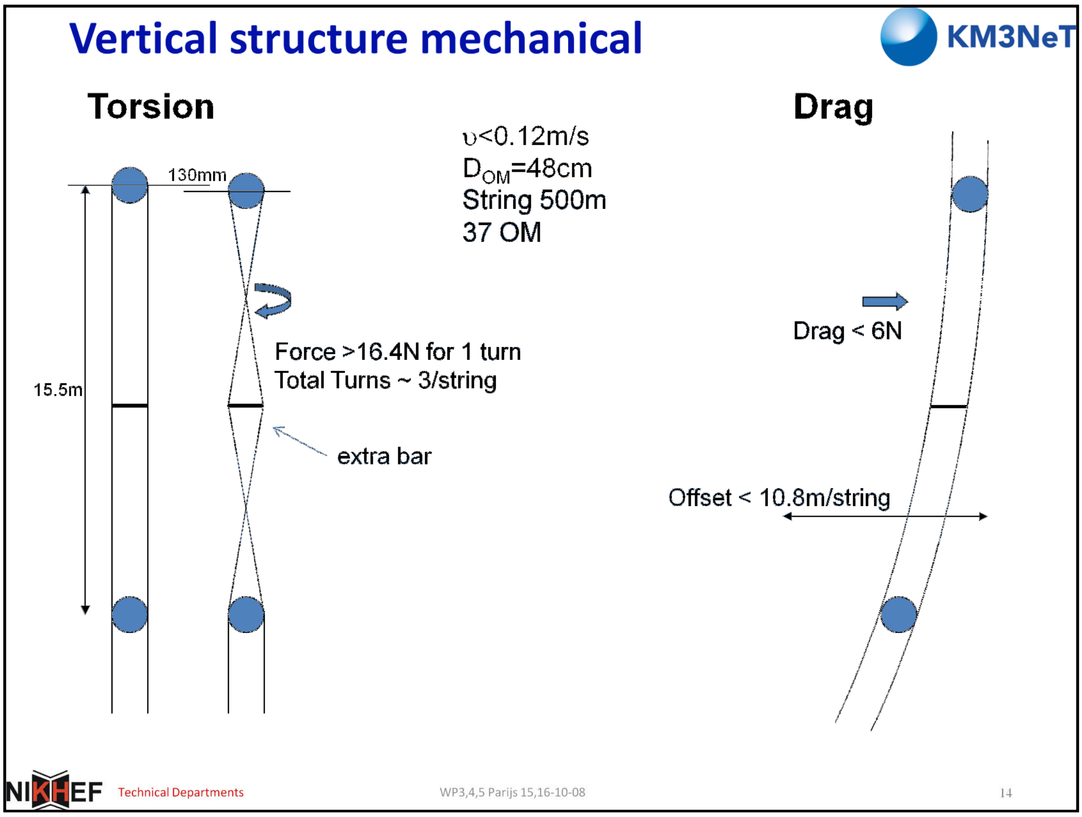
The present proof of concept is 100m long with 3 breakouts of 2 copper wires and two fibers.

In the real model there should be added 2 solid state resettable fuses to prevent string power loss by shorting or implosion of one optical module. Tests for the fuse concept are worked out.



Drag;

Maximum sea current 0.12 m/s.

Drag force on a 0.48 m sphere 0.56866 N

Drag force on a 0.02 m diameter cable 0.15605 N/m for 15.5 m 2.42 N.

To improve the torsion stiffness we use two cables.

Horizontal 0.568 +2* 2.42=5.4 N and vertical 250 N tg=5.4/250=0.0216

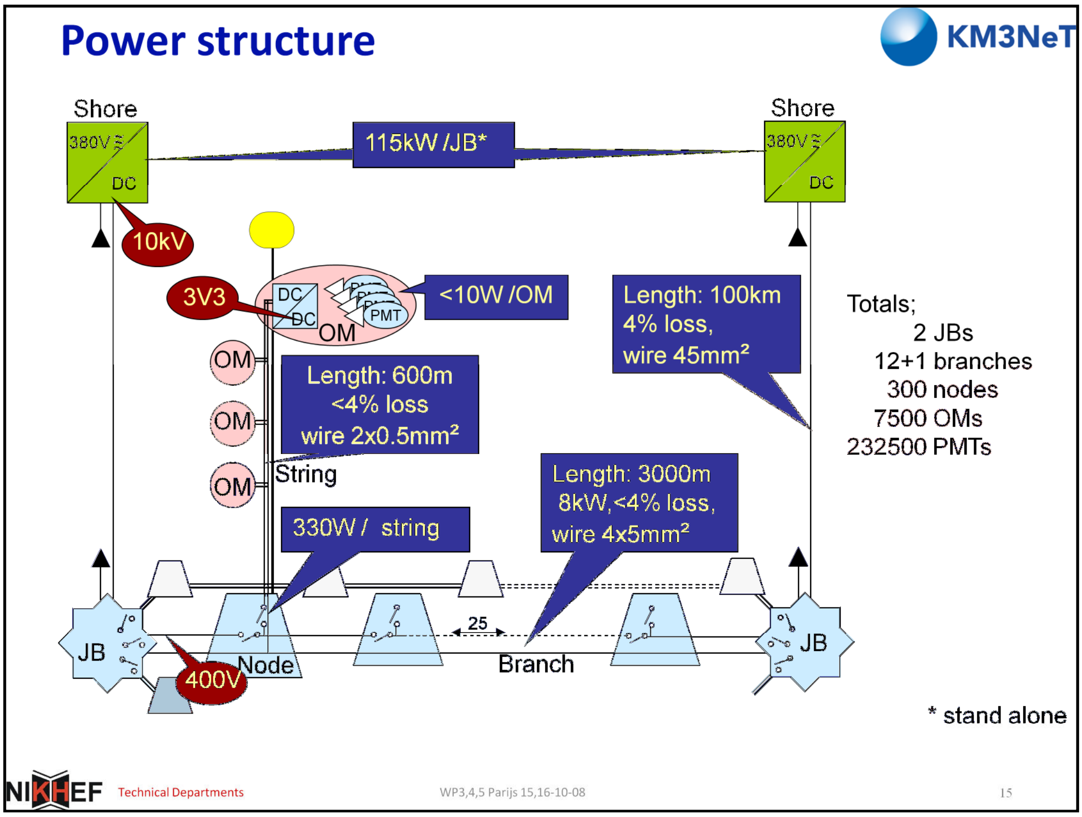
Horizontal offset for 500 meter height 500*0.0216=10.8 meter.

Torsion stiffness of the cable:

When the vertical string is built up with a cable on every side of the sphere, and these cables are coupled together then the torsion stiffness of this cable is almost 0. The cable has some torsion stiffness if the parts stay apart on a distance of 0.5 m. The stiffness depends on the vertical distance. If we use the vertical space of 15.5 meters between the spheres then a 180 degrees rotation gives a vertical displacement of 2* (7.75^2-0.45^2)^0.5-7.75=26*10^-3 meters. With 200 N force in the cable the displacement needs 5.2 Nm energy. Torsion stiffness 5.2/pi=1.655 Nm/rad. When the maximum drag force of 6 N works on the maximum radius of 0.24 meters the rotation angle will be (6*0.24)/1.655=0.87 rad.

To be safe we put a spoke between the cables. This will reduce the vertical distance to 7.75 meters.

With 200 N force in the cable 360 degrees rotation changes the vertical distance between the spheres by 130 mm. Change in energy 0.13*200=26 Nm. Maximum allowable force on the circumference of the sphere 26/(pi*0.5)=16.4 N.



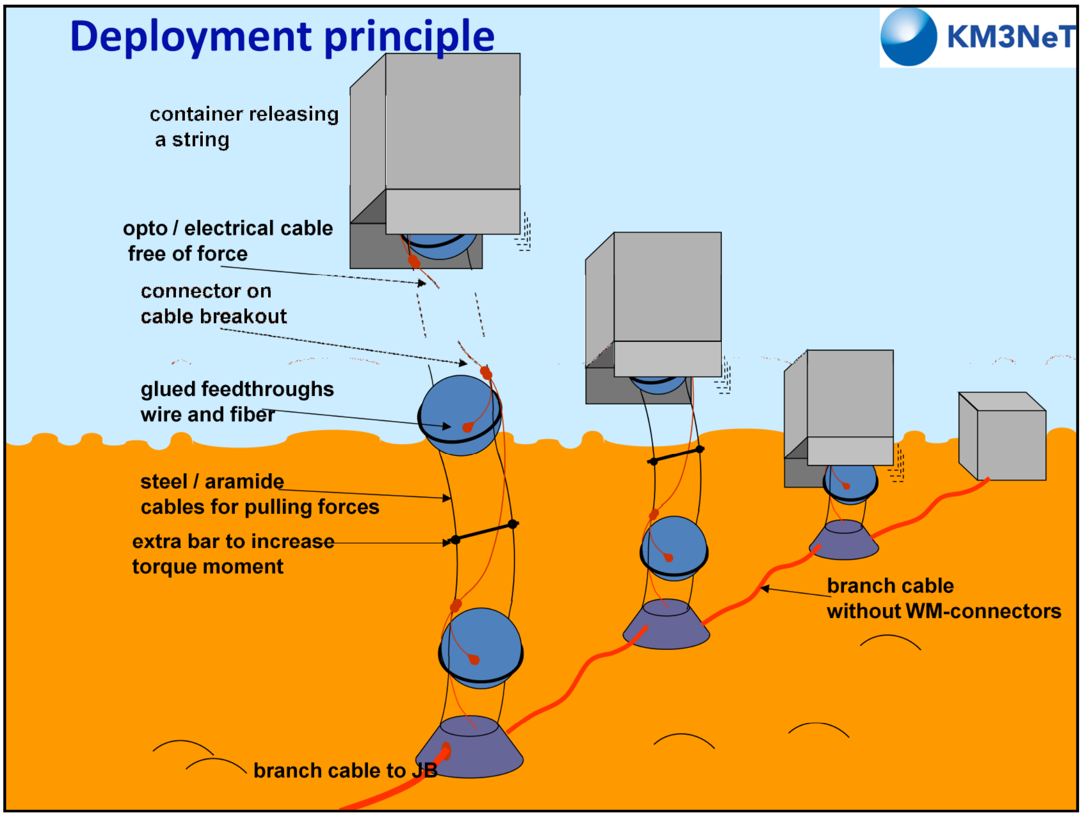
All these numbers are indicative and have to be justified when details are worked out.

By using 2 JBs and shore connections (or more) we achieved more redundancy. Think at the cable faults by Antares and Nemo.

Costs should be in the order of 2% of the installation costs.

In general to keep grip on the power design a severe power budget coordination will be necessary as well as for grounding and voltage levels, according the experience of Antares.

Each voltage level means a DC/DC conversion with its own efficiency and dissipation.



Each vertical structure is stored in a 20’ ISO standard shipping container (6x2.4x2.5m).

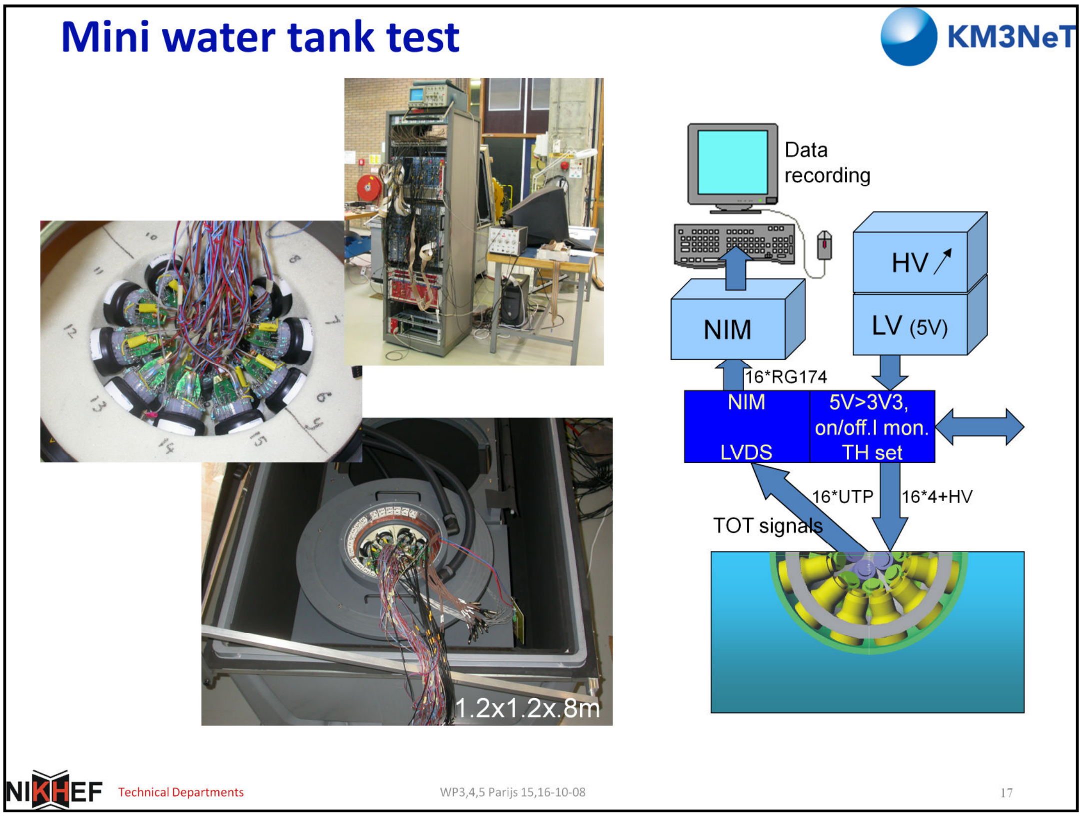
During deployment all containers will have a density near seawater and will sink very slowly. In this way this whole branch can be positioned on sea-bottom. After positioning the tubes are released and the spheres will rise to their position.

So a number of containers can be deployed interconnected and no wet-mateable connectors in between.

Each container can be a standard sea container with each sphere on top of the previous, like the tower deployment of NEMO.

With a sphere > 17” no buoyancy will be necessary.

This concept fits well in the power setup presented at Rome.
The vertical cable for communication/power can be split in two and interleaved daisy chained along the vertical stress members.



Mini water tank test

Set up to do tests for

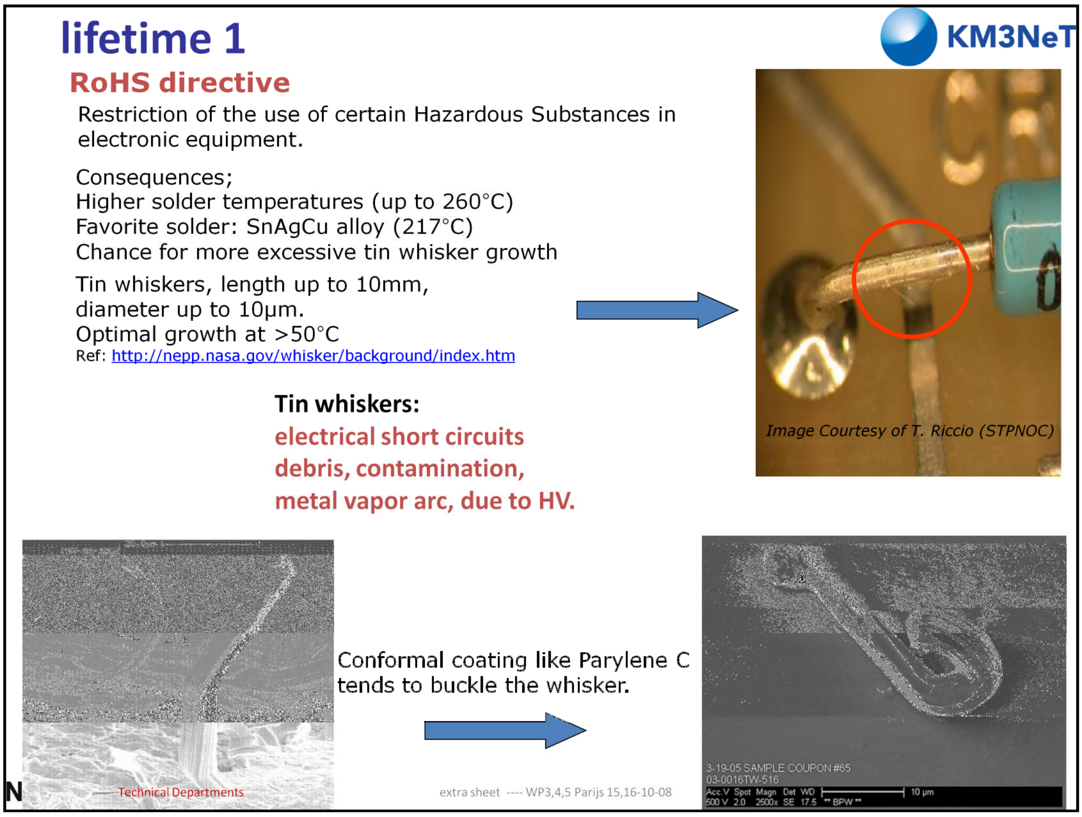
-Refraction measurements
  in a dry tank, with a green LED

-PMT-tests
  in a dry tank, with a green LED

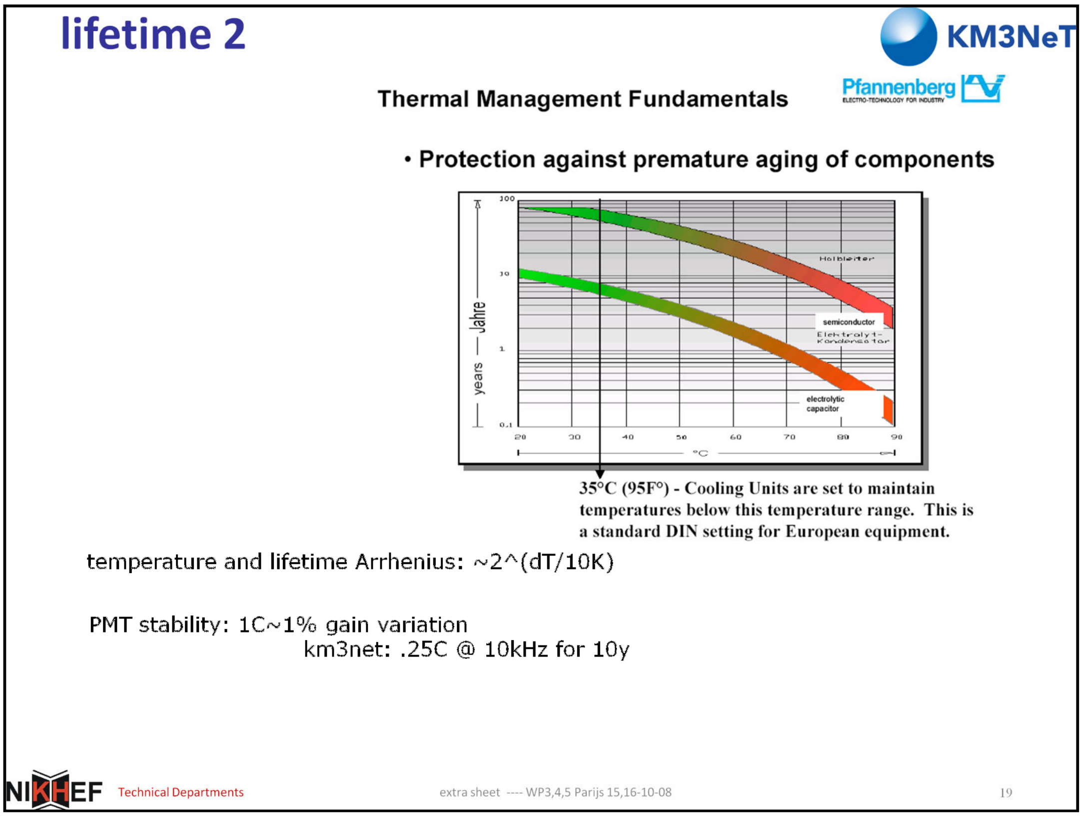
-PMT-tests
  with water saturated with potassium

Started with temporarily electronics.

Each time new electronic is available we can test a complete halve sphere.

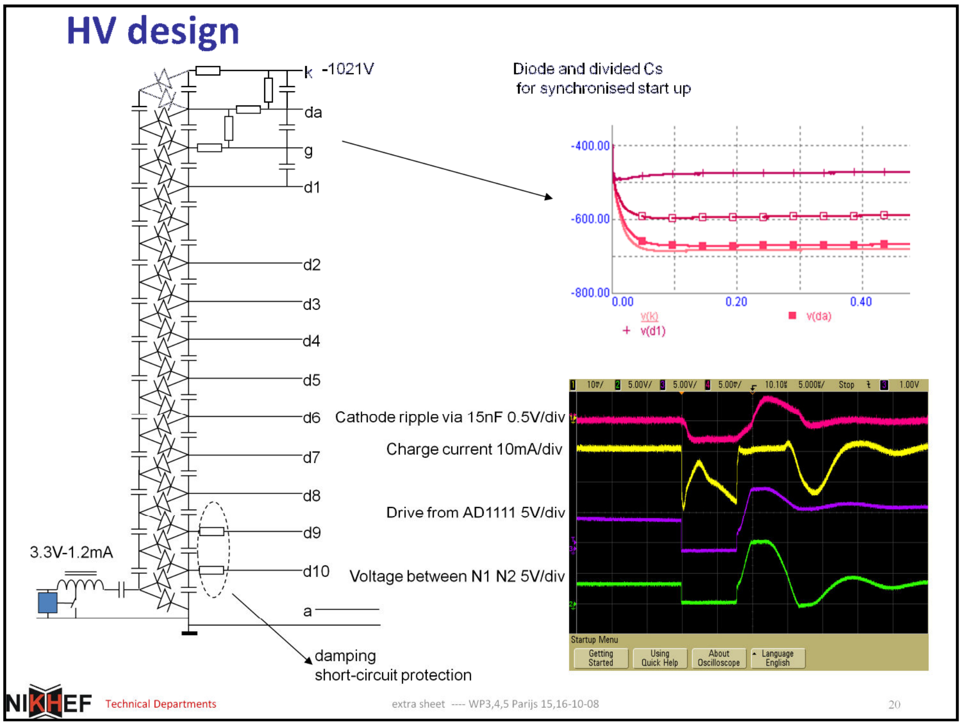


Special valid for miniaturized HV circuits.



Silicium components are lifetime limited too!

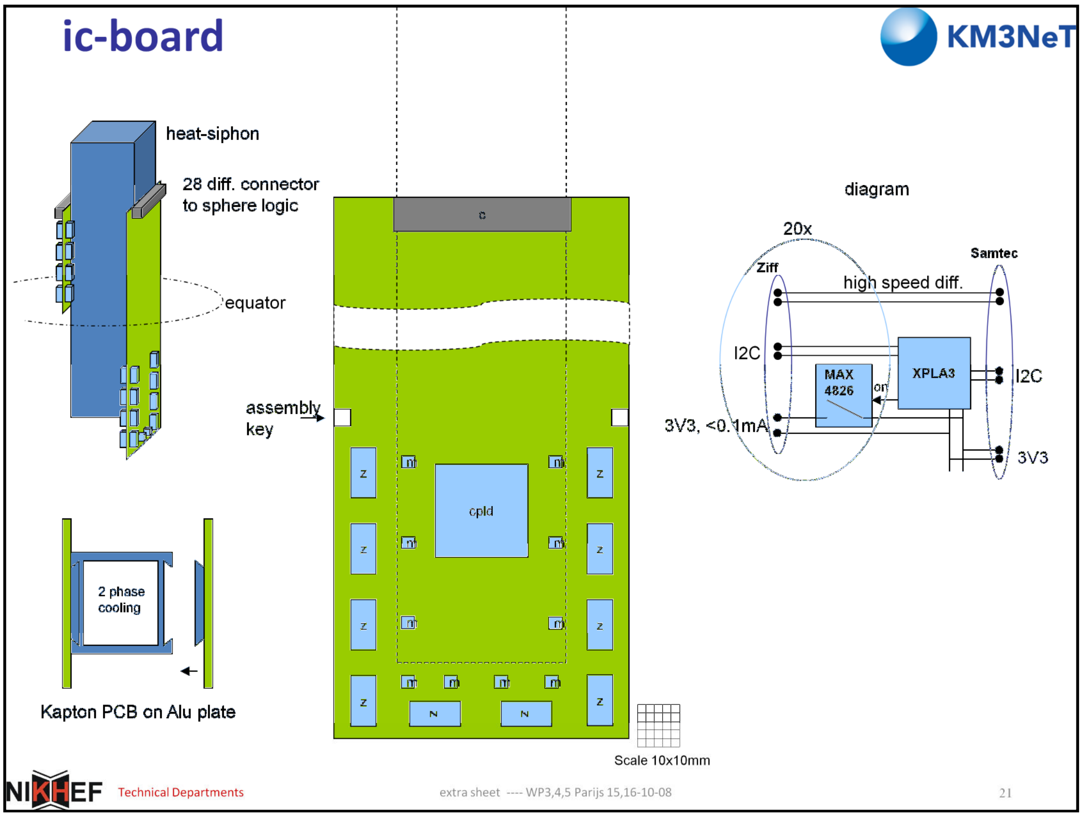
If electrolytic capacitors are needed, use big sized types with minimal 5000h on 105°C which means more then 10 years at 60°C.



The extra serial resisters in the high numbered dynode paths prevents also ringing. The splitting of the capacitors between cathode and dynode 1 prevents reverse voltage during start up due to the resistor-capacitor charging times.

Expected power dissipation: <10mW (for a passive resistor divider: 30mW). Because the low dissipation each PMT unit can have its own HV system. In this way maximum flexibility to tune the HV and maximum redundancy is achieved.

If voltage change; TT, TTS, Tr will change. Mainly due the voltage change in the focusing part (cathode to d1). So it is worthwhile to test a model with a steady voltage in the cathode area and tune the gain only in the dynode trajectory.



cpld coolrunner package: TQFP(176) (22x22mm), type: XCR3256XL
m 3V3 switch package: uDFN(1x1.5mm),
type: http://datasheets.maxim-ic.com/en/ds/MAX4826-MAX4831.pdf
z Ziff connector package: ~12x6mm
c Samtec connector 28*diff.pair package: ~42x7.3mm, type: QSE-28-01

Remarks

-Lower sphere; with the keys in the PCB and extra plates, pressure can be add to fixed the connector to the sphere logic receptacle during the mounting process. This process will asked for less room to manipulate the connection between central- and interconnection board.

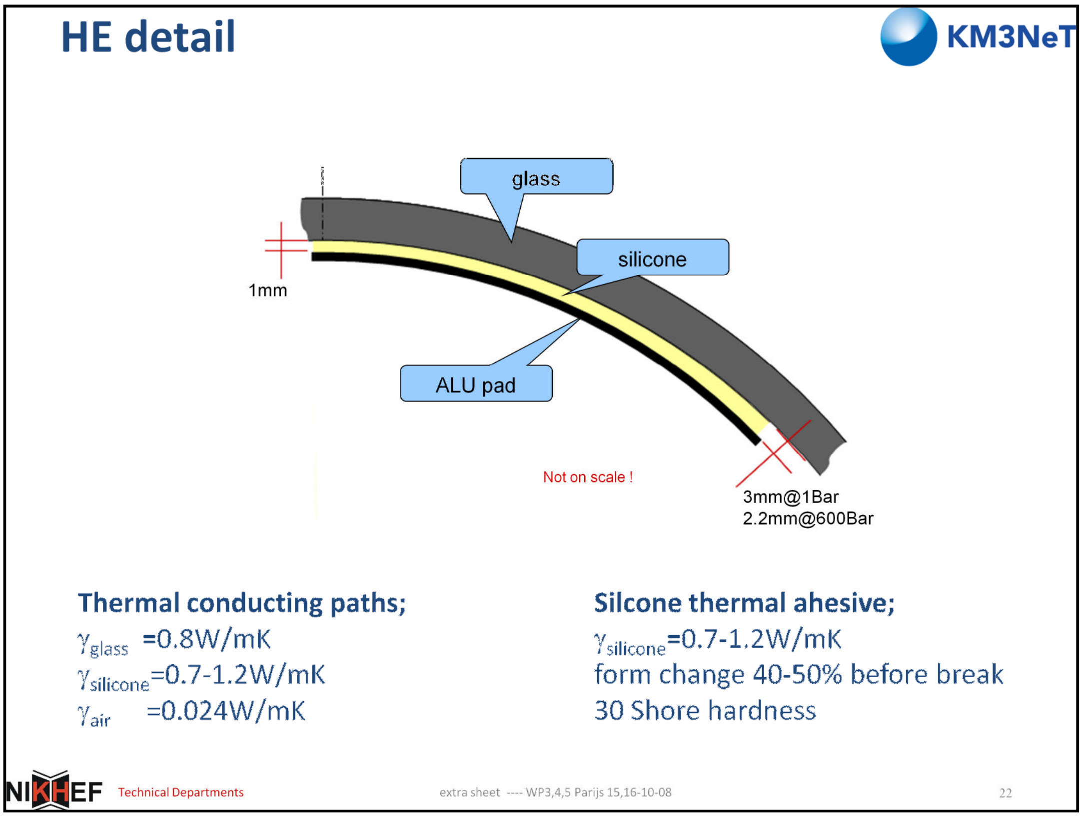
-More space for extra electronics connected directly to the CPLD (large CPLD needed!) can be created on the PCB .

-On the empty sides of the heat-siphon extra electronics can be placed connected by the spare Ziff connections (1 for the lower sphere, 8 for the upper sphere (31 PMT's and 20 I/Os/PCB)).

-The PCB is glued to an Alu-plate:

-As heat spreader and assure contact to the heat-siphon (diss. <100mW/PCB).

-Fixing mechanical the PCB by the mechanical key between heat-siphon and Alu-plate.



The heat exchanger (HE) to glass is mount with a 1mm thick silicon based glue in the middle and 3mm thick at the outside (f.i. Type LTR3292 silicone).
The deformation of the 432mm sphere under 600 bars pressure is 2.7 mm.
+ The relative deformation is 2.7/432=0.625 %
+ The aluminum cooling pad of the heat exchanger is glued to the glass with silicon based glue.
+ On the glass-glue interface the glue has to follow the 0.625 % shrinkage of the glass.
+ Hardness >30 Shore silicone rubber will be used as glue. (Silicon rubber is widely used for sealing dynamically moving joints).
+ Silicon can have a 40% - 50% elongation to break.
+ The maximum movement in this application 0.625 % times the aluminum pad radius of 129 mm is 0.8 mm.
+ With a glue thickness of 3 mm at the edge the movement is only 27 % of the thickness
+ The silicone based glue will improve the heat transfer path compared to air (Air=0.024 W/mK, Glass=1.2W/mK, Silicone=0.7-1.2 W/mK). The temperature difference between glass and HE will be 0.3°C.

The silicon glue is subject of an optimization process.