Timing system and clock distribution KM3NeT

Standard White Rabbit for KM3NeT

- **Diego Real** on behalf of the KM3NeT Collaboration

IFIC
INSTITUT DE FÍSICA CORPUSCULAR

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

11th April 2022

KM3NeT Collaboration

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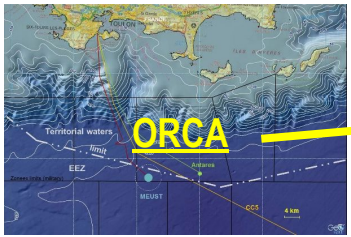
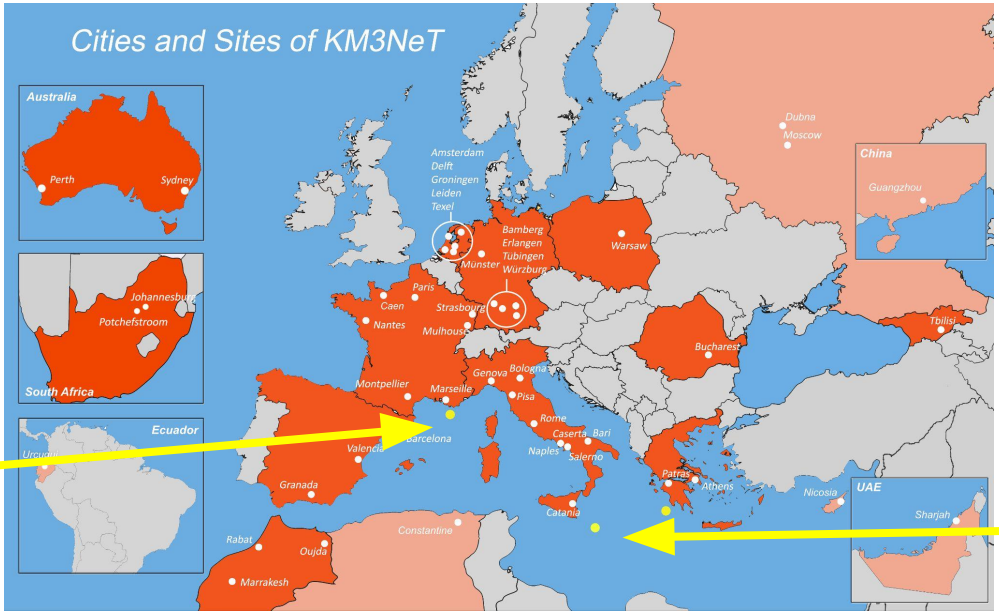
Two detectors, same technology, different physics objectives

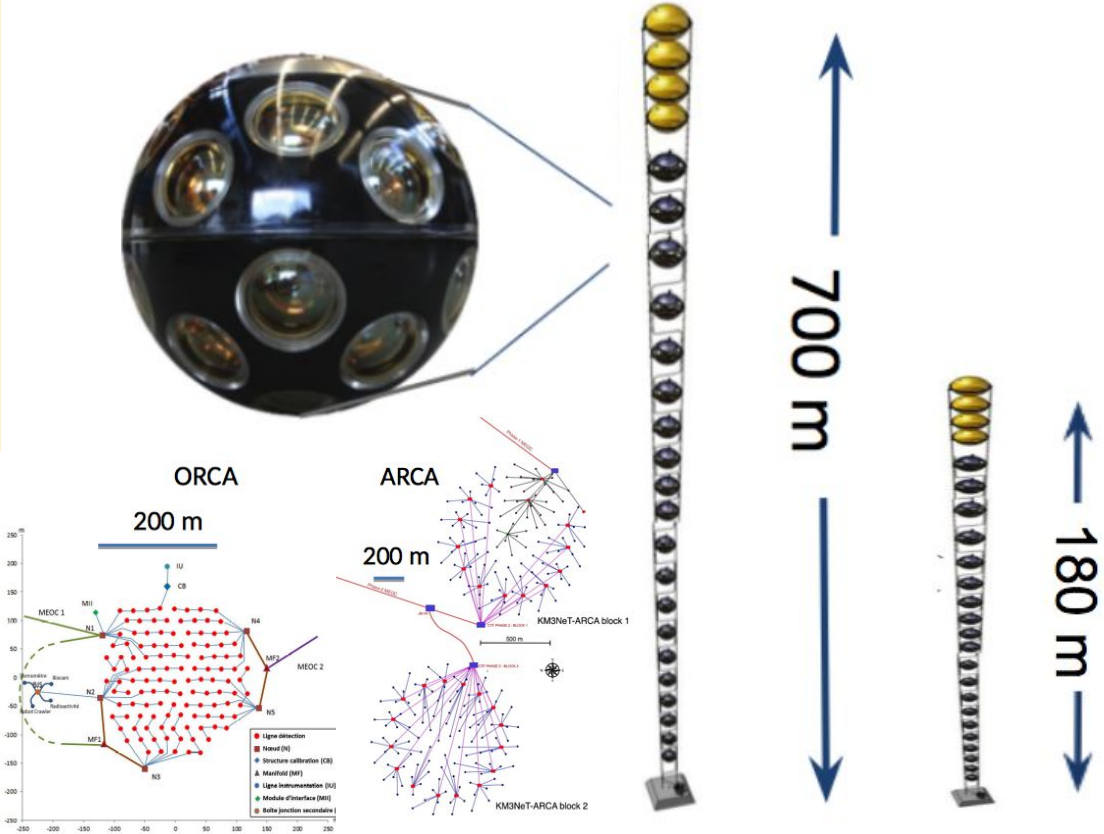




> 50 Institutes
> 250 Physics & Engineers

KM3NeT Detection Unit

- **18 DOMs per DU**
- **ARCA:** 36 m spacing, DUs 700 m height
- **ORCA:** 9 m spacing, DUs 180 m height
- Two parallel ropes, 4 mm diameter
- Four buoys to **sustain DU flotation**



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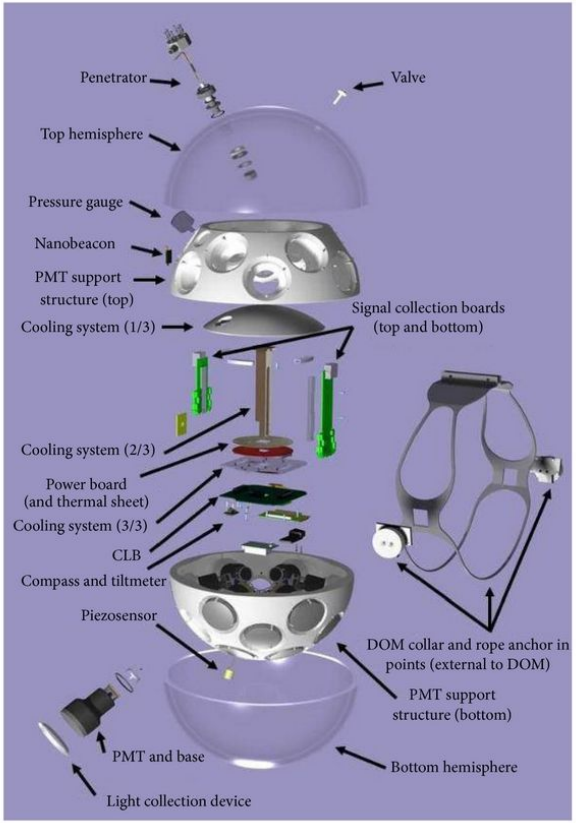
KM3NeT Digital Optical Module

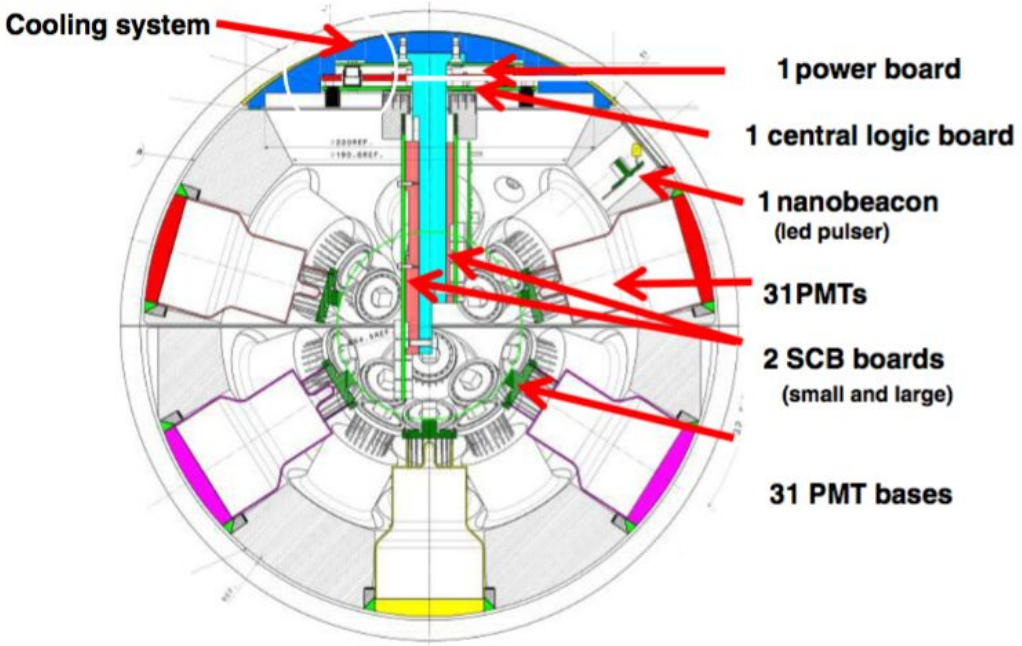
- 17” glass sphere, transparent
- Aluminium cooling block
- 31 3” PMTs
- Two hemispheres (19 PMTs bottom, 12 PMTs superior)
- Acquisition Electronics
- Piezo sensor
- Nanobeacon



KM3NeT Acquisition Electronics

Acquisition electronics:

- 1 Power Board (PB)
- 1 Central Logic Board (CLB)
- 2 Signal Collecting Boards (SCB)
- 31 PMT bases



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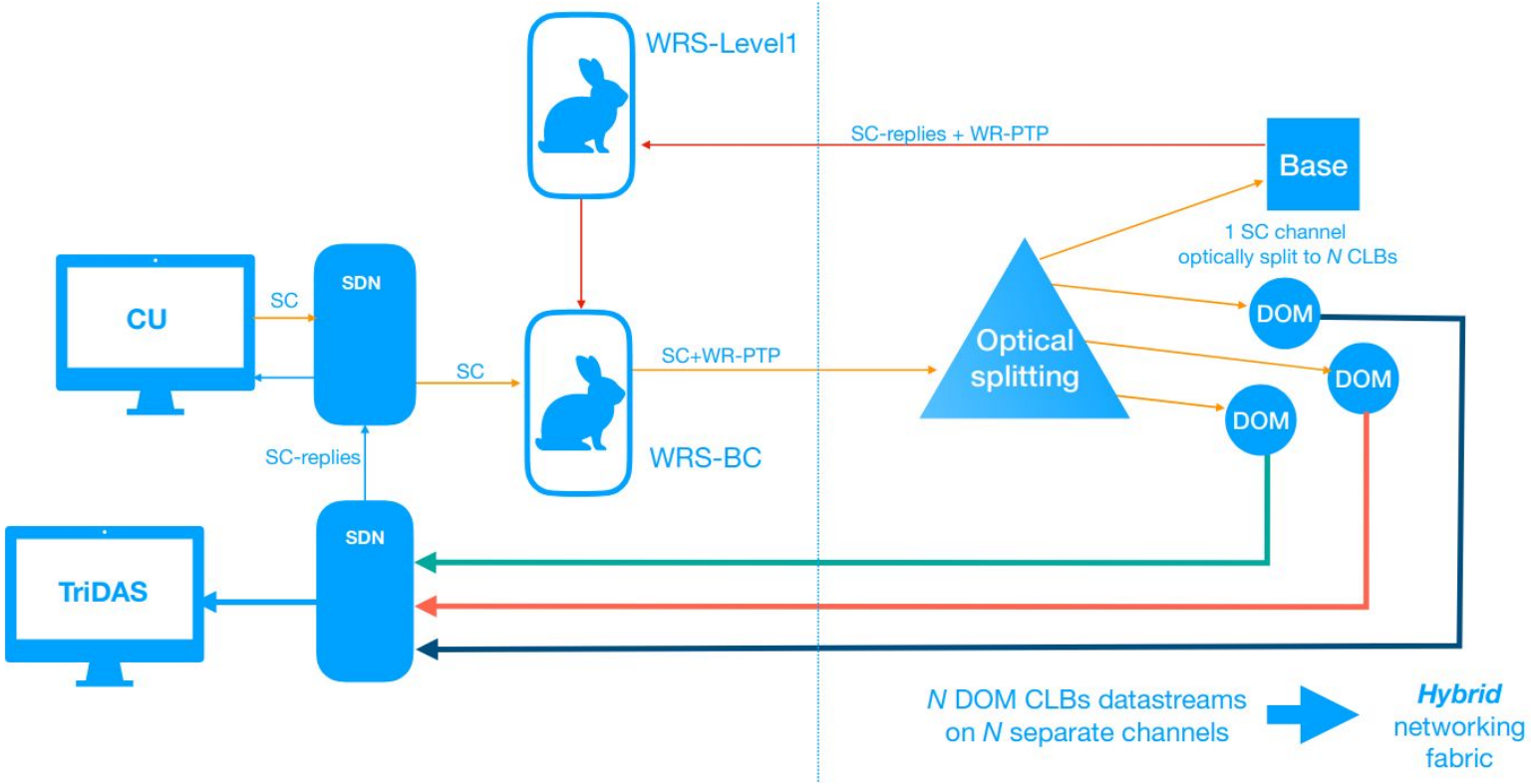
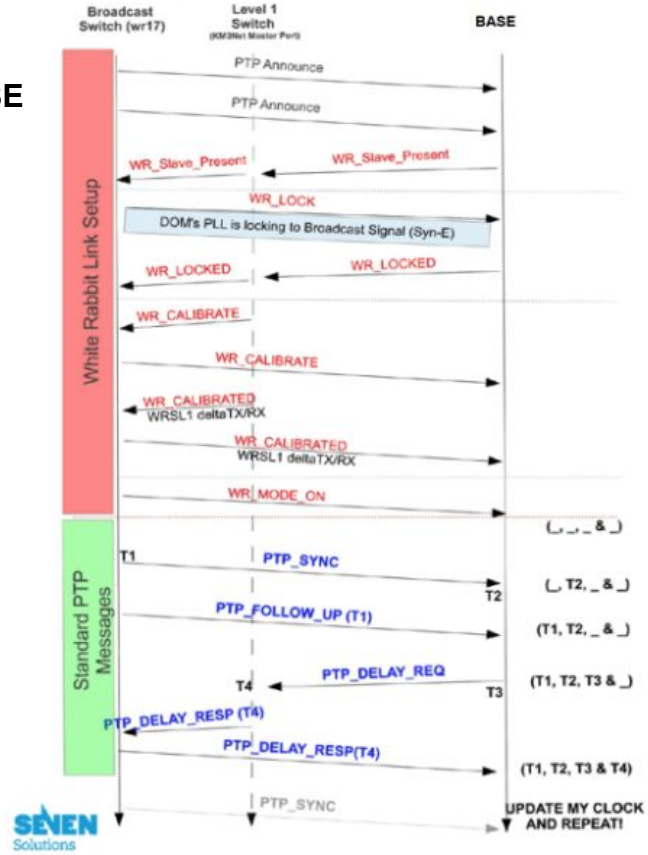
Broadcast White Rabbit Network



Time distribution -ns precision-.

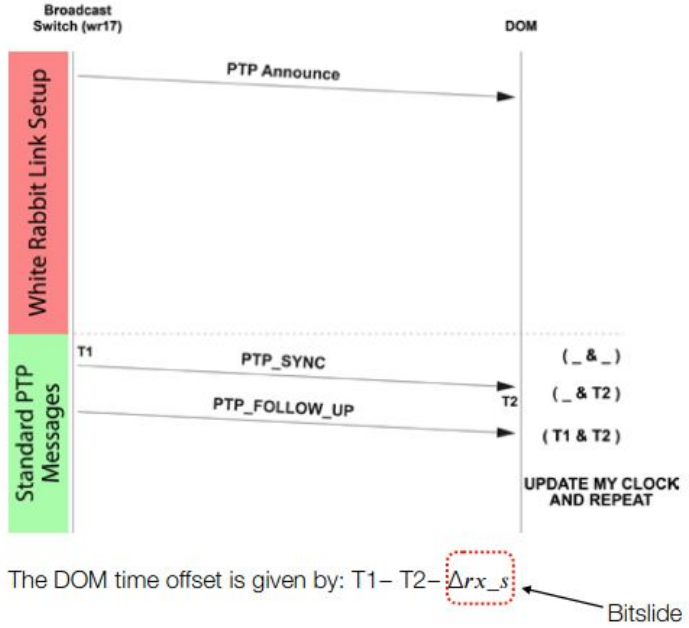
Broadcast White Rabbit Network

DU-BASE



DOM Simplified WR state machine

note: the link setup stage is concurrent in all DOMs



Caveats:

- Round-trip time stability is monitored with Base Module and applied online to collected data at TriDAS level
- Stable temperature and fixed length of connections necessary

New Time Distribution Design

The design and validation of the Standard White Rabbit System (Point-to-point connections. Data communication and time distribution in the same line) in KM3NeT:

Electronics: New Carrier Development + SCB reliability assessment + new CLB version

Optics system: New optical network + new transceivers

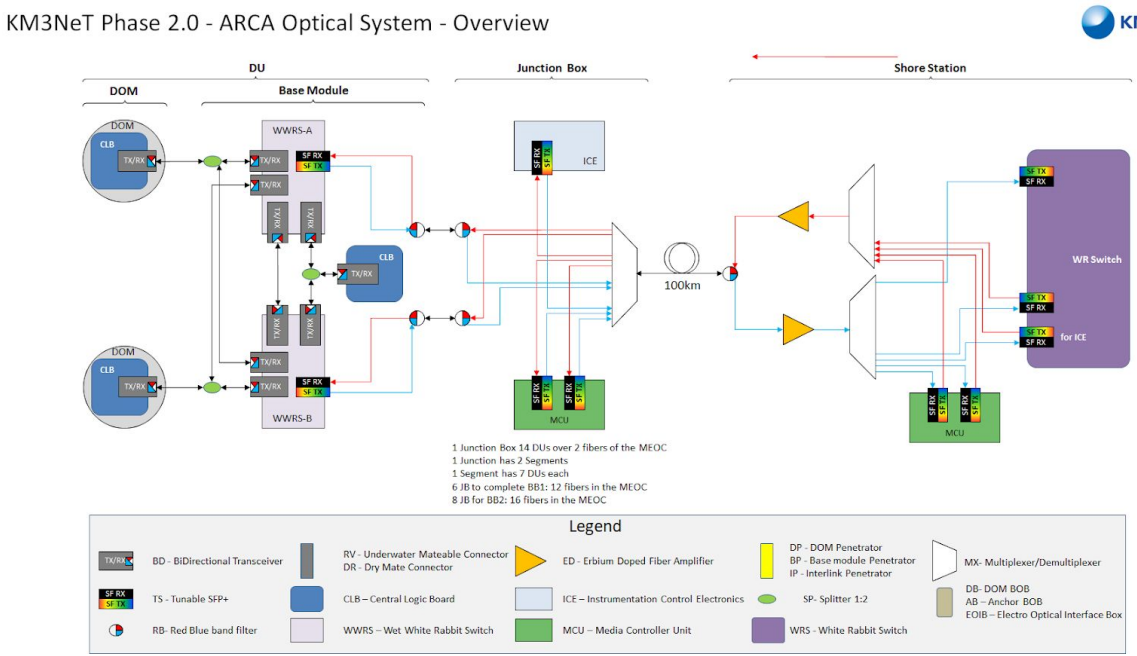
Power System: Additional power at the DU Base

DAQ: Network redesign + redundancy management

Calibration: New calibration plan

It replaces the current time distribution system based in a modification of the White Rabbit protocol, which uses a broadcast line to distribute time

Standard White Rabbit Network



- 2 tunable SFP+DWDM long range transceivers for connecting with the on-shore station
- 2 WRS per DU: 9 DOMs connected per WRS
- 1 CLB connected to one of the two WRSs
- 23 bidirectional short range transceivers (**high reliability**) for DOM connections (9x2), CLB connection (3), inter-WRS connection

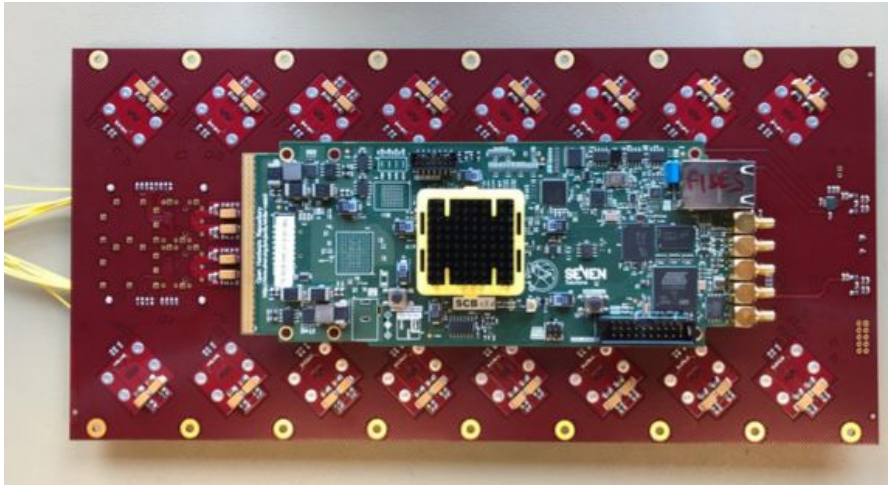
2 WRS needed at the bottom of the DU

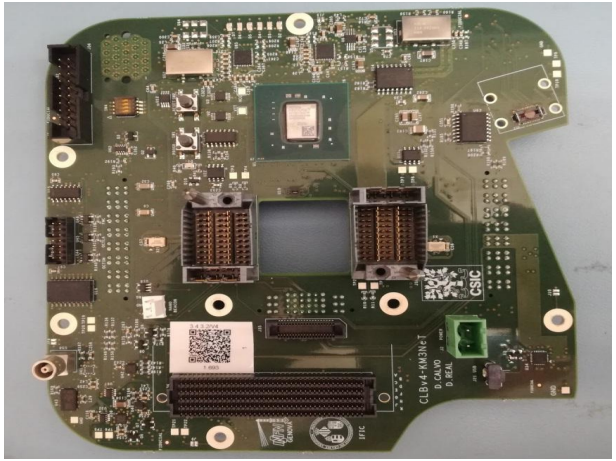
SCB + New carrier

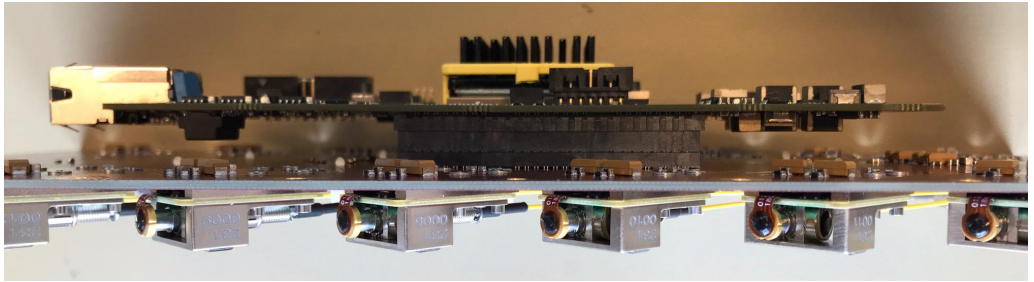
SCB: Switching Core Board. Main board of the WRS (**reliability assessment**)

Carrier designed by KM3NeT with Glenair transceivers

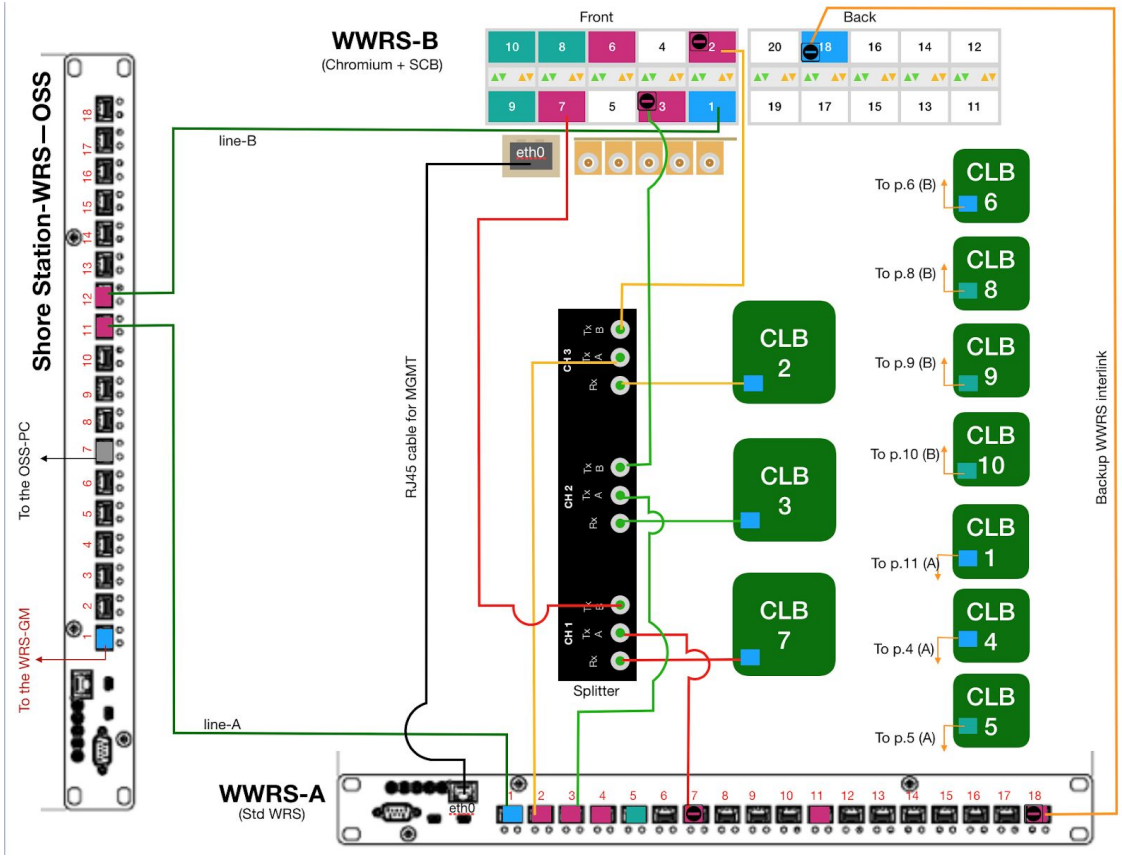
CLBv4: New KM3NeT WR node with Glenair transceivers







First Test Bench



Scheme of the first tests performed

Possibility to reroute traffic from one WRS to the other

One WRS configures the other one

Two levels of redundancy (upstream channel & WRS)

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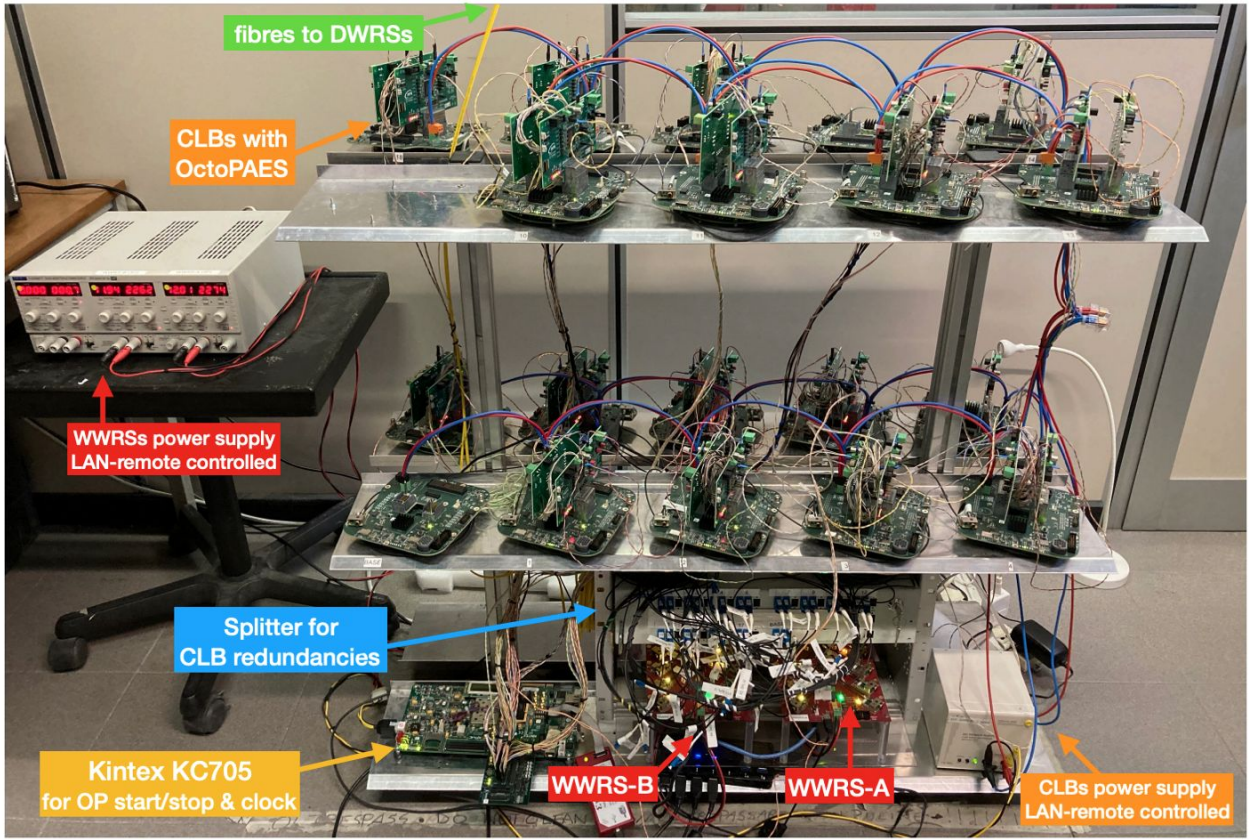
Test Bench



Reliability

FIDES (theoretical procedure)

Applied already in KM3NeT

HALT (procedure)

Under application in combination with HASS tests -> Upgrading from ESS

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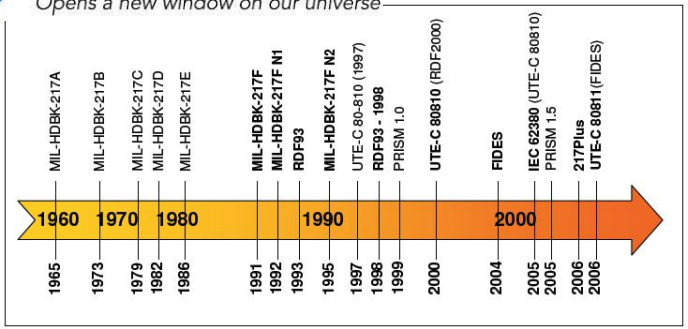
FIDES

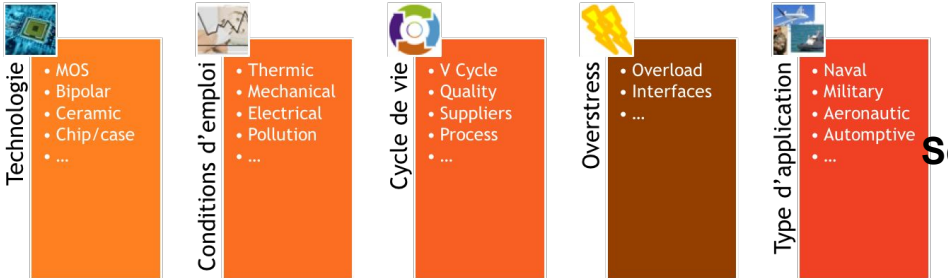


FIDES methodology:

- Include most recent technologies
- Consider all factors that could affect reliability

FIDES handbook (2009) developed by:

- Airbus France, Eurocopter, Nexter Electronics, MBDA missile systems (chef de projet), THALES Avionics, THALES Services SAS, THALES Systèmes Aéroportés, THALES Underwater Systems,
- And by DGA (development fund providing)
- GTR Fides open to all users Don't hesitate to contribute



Scientific ->

MBDA MISSILE SYSTEMS
AIRBUS
nexter ELECTRONICS
THALES
THALES RESEARCH & TECHNOLOGY
THALES AVIONICS
THALES
THALES UNDERWATER SYSTEMS
THALES
THALES AIRBORNE SYSTEMS
eurocopter

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FIDES Results

WR SWITCH			
Current Design		KM3NeT Upgrade	
WR SCB			
FIT	MTBF	FIT	MTBF
2937	340483	794	1259445
Chromium board (carrier)			
FIT	MTBF	FIT	MTBF
639	1564945	435	2298850
TOTAL		TOTAL	
3576	279642	1229	813669

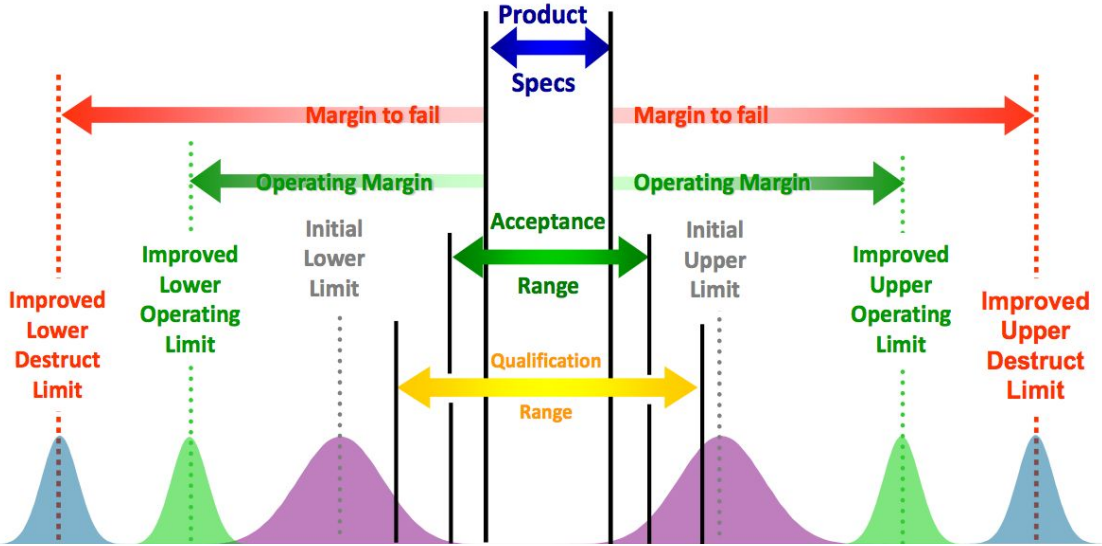
290 % improvement in the reliability of the WRS

Mainly due to decoupling capacitors. Better part choice

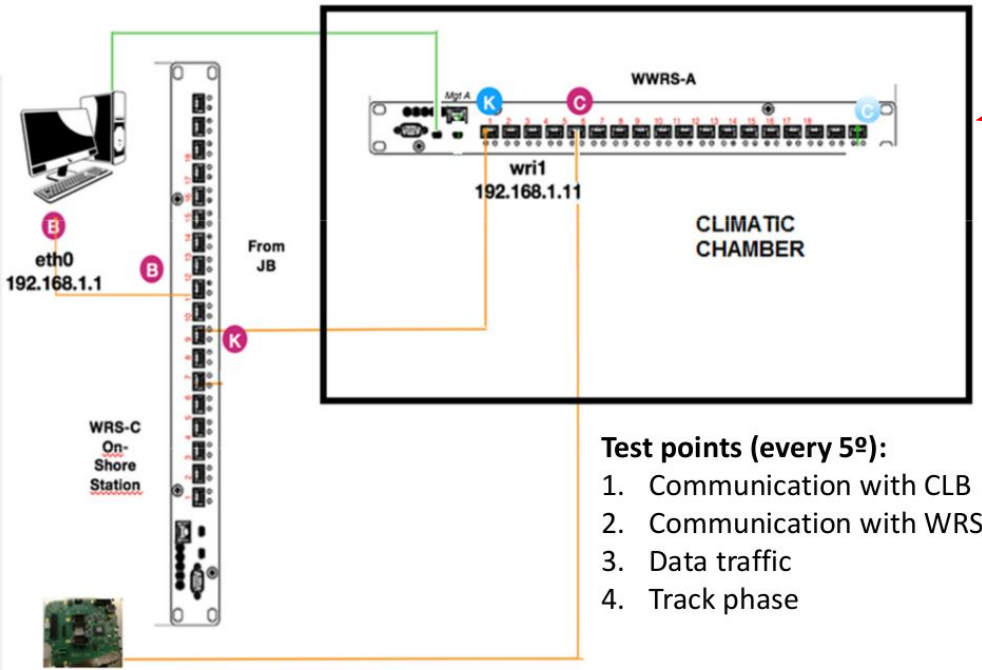
HALT

Highly Accelerated Life Test (HALT) is a design test used to improve the robustness/reliability of a product through test-fail-fix process where applied stresses are beyond the specified operating limits. The main idea is to find **weak points** in the **design** in an **early stage** in order to correct them and **improve and optimize the design in a reliable way**

This applies only to a few boards in the design stage.

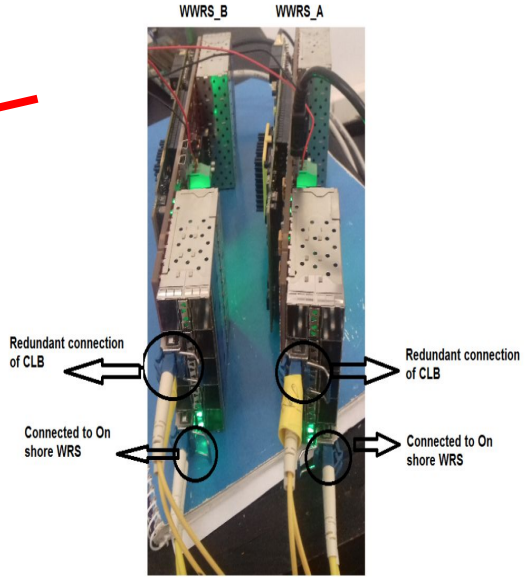


HALT tests



Test points (every 5º):

1. Communication with CLB
2. Communication with WRS in the chamber
3. Data traffic
4. Track phase



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HALT Results

	WWRS-A (°C)	WWRS-B (°C)	*Mean (°C)*	HASS (80% OL) (°C)
UOL -Upper Operating Limit	100	95	*97.5*	**78**
UDL- Upper Destructive Limit	100	95	*97.5*	
LOL - Lower Operating Limit	-40	-40	*-40*	**-32**
LDL - Lower Destructive Limit	-40	-40	*-40*	

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CONCLUSIONS

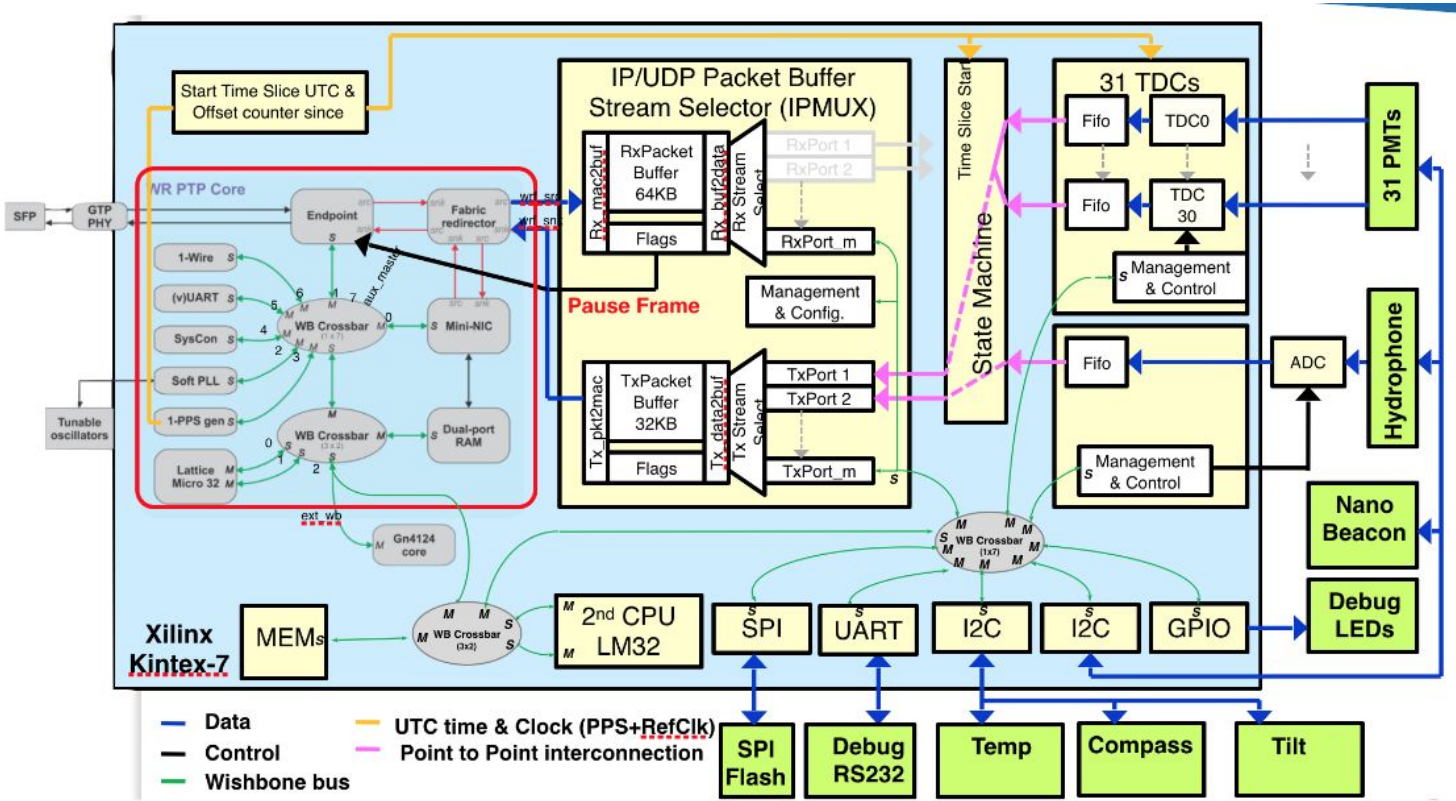
Simplification of the Broadcast Optical Network by using WRSs at the bottom of the KM3NeT DUs

A high reliable SCB has been designed + a carried adapted to KM3NeT needs (using high reliability transceivers) + a new version of the KM3NeT WR node (CLV4)

Qualified. Production of components started this year (2022)

THANKS!

QUESTIONS?


Start Time Slice UTC & Offset counter since
IP/UDP Packet Buffer Stream Selector (IPMUX)
RxPacket Buffer 64KB
Flags
Rx_mac2buf
Rx_buf2data
Rx Stream Select
RxPort 1
RxPort 2
RxPort_m
Management & Config.
Pause Frame
TxPacket Buffer 32KB
Tx_pkt2mac
Tx_data2buf
Tx Stream Select
TxPort 1
TxPort 2
TxPort_m
Time Slice Start
State Machine
31 TDCs
Fifo
TDC0
TDC 30
Management & Control
31 PMTs
ADC
Hydrophone
Nano Beacon
Debug LEDs
WR PTP Core
SFP
GTP PHY
Endpoint
Fabric redirector
1-Wire
(v)UART
SysCon
Soft PLL
1-PPS gen
Lattice Micro 32
WB Crossbar
Mini-NIC
Dual-port RAM
Tunable oscillators
ext_wb
Gn4124 core
Xilinx Kintex-7
MEMs
2nd CPU LM32
SPI
UART
I2C
I2C
GPIO
SPI Flash
Debug RS232
Temp
Compass
Tilt
Data
Control
Wishbone bus
UTC time & Clock (PPS+RefClk)
Point to Point interconnection