KM3NeT
Opens a new window on our universe

VNIVERSITAT DE VALÈNCIA

IFIC INSTITUT DE FÍSICA CORPUSCULAR

CSIC

Status of the DOM electronics

RICAP 2024, Roma 26th September

Presenter D. Real **Authors: D. Real and D. Calvo**
on behalf of the KM3NeT Collaboration

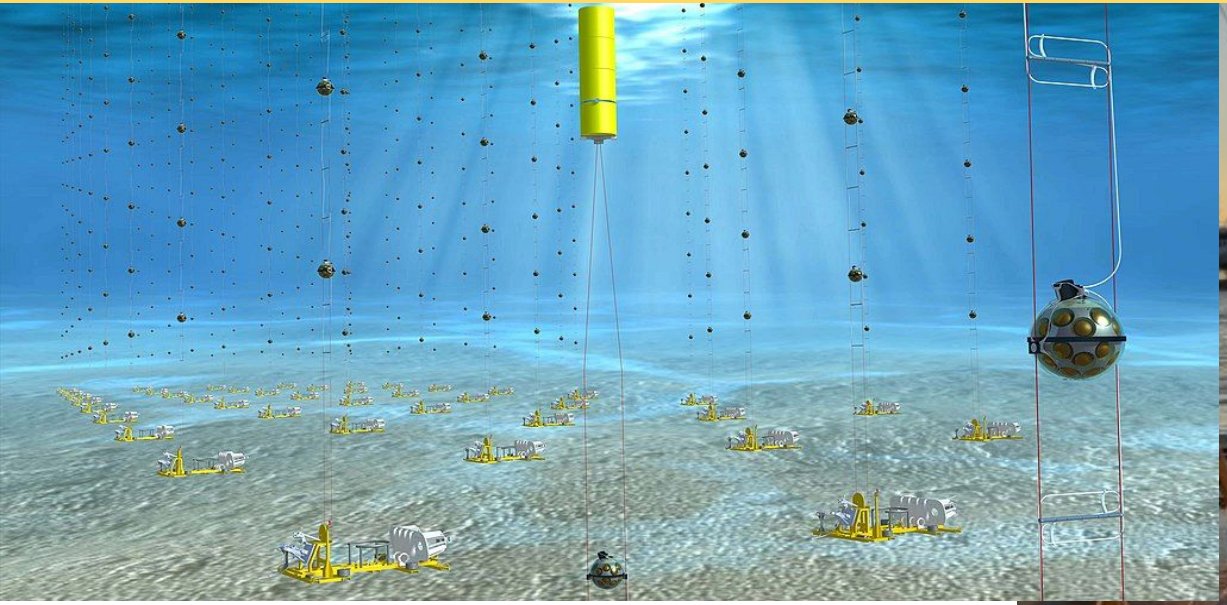
ASFAE ASTROFÍSICA Y FÍSICA DE ALTAS ENERGÍAS

GVANEXT
GENERALITAT VALENCIANA
Plan de Recuperación, Transformación y Resiliencia
Financiado por la Unión Europea NextGenerationEU

OUTLINE

1. KM3NeT
2. Detection Unit
3. Digital Optical Module
4. Digital Optical Module Electronics
5. Latest Developments
6. Conclusions

KM3NeT Introduction



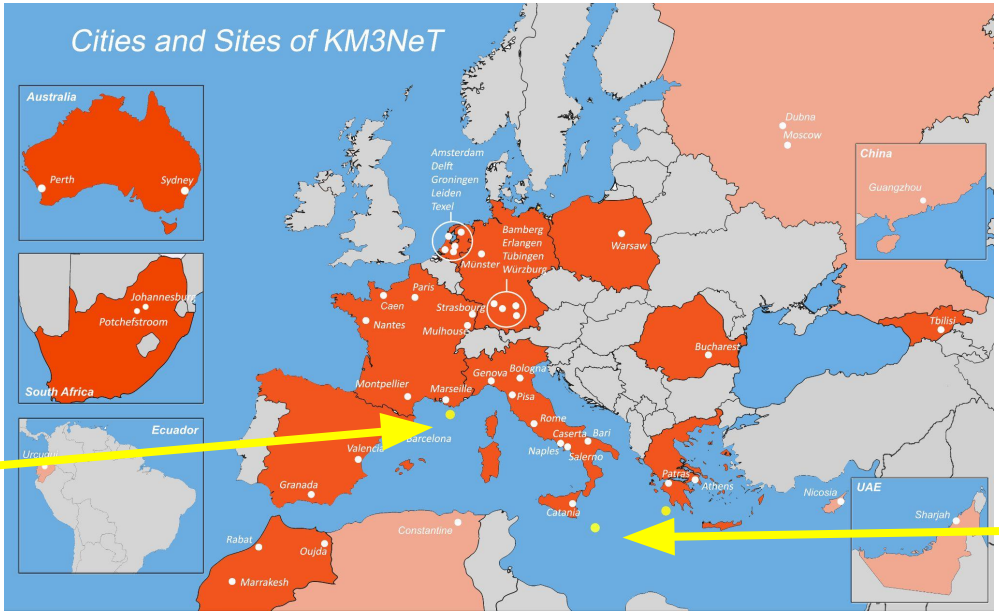
ARCA: 230 Detection Units with 18 DOM (4140 DOM) -> 28 DUs deployed and operational

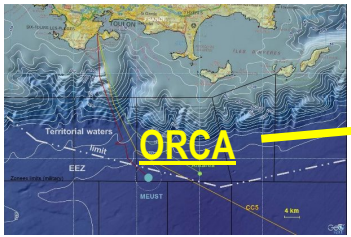
ORCA: 115 Detection Units with 18 DOM (2070 DOM) -> 23 DUs deployed and operational

KM3NeT Introduction

D. Real

Two detectors, same technology, different physics objectives





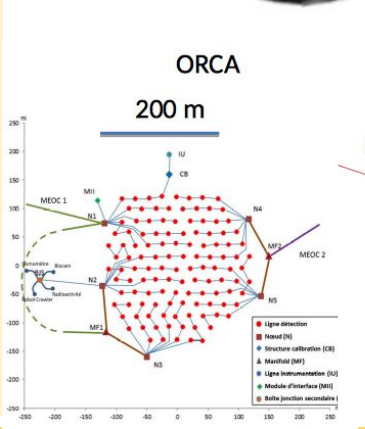
> 50 Institutes
> 250 Physics & Engineers

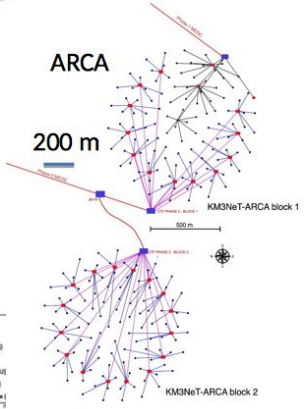
ARCA: 230 Detection Units with 18 DOM (4140 DOM) -> 28 DUs deployed and operational

ORCA: 115 Detection Units with 18 DOM (2070 DOM) -> 23 DUs deployed and operational

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**



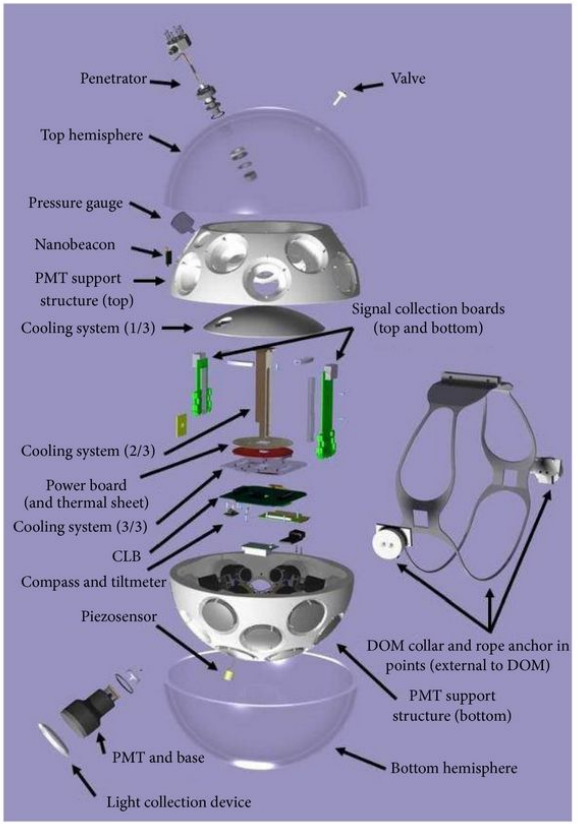


700 m

180 m

KM3NeT Digital Optical Module

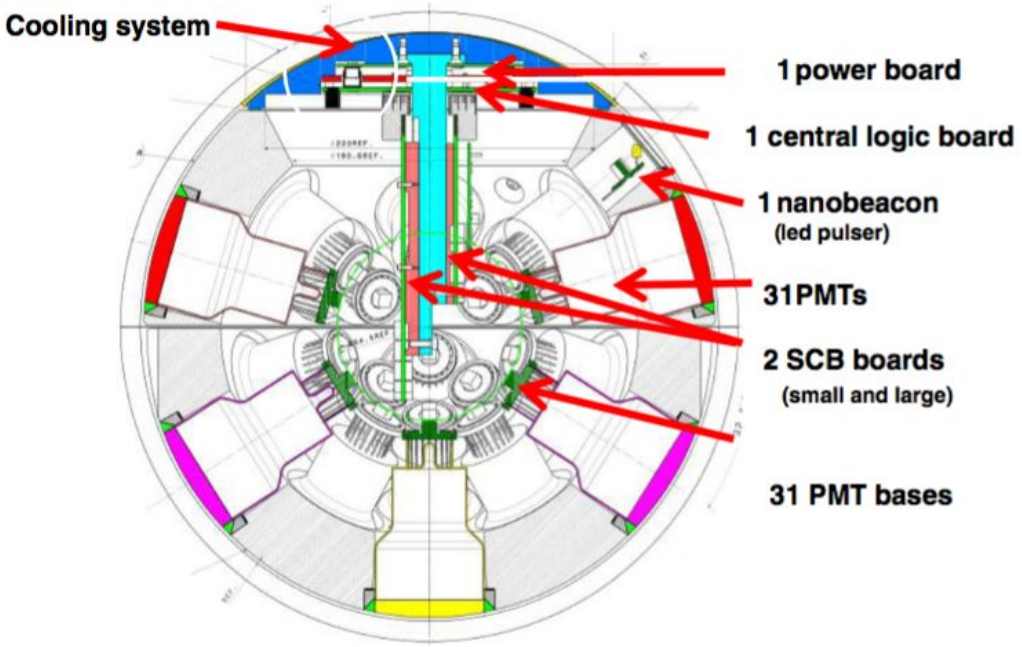
- 17” glass sphere, transparent
- Aluminium cooling block
- 31 3” PMTs
- Two hemispheres (19 PMTs bottom, 12 PMTs superior)
- Acquisition Electronics
- Piezo sensor
- Nanobeacon



Digital Optical Module Electronics

Acquisition electronics:

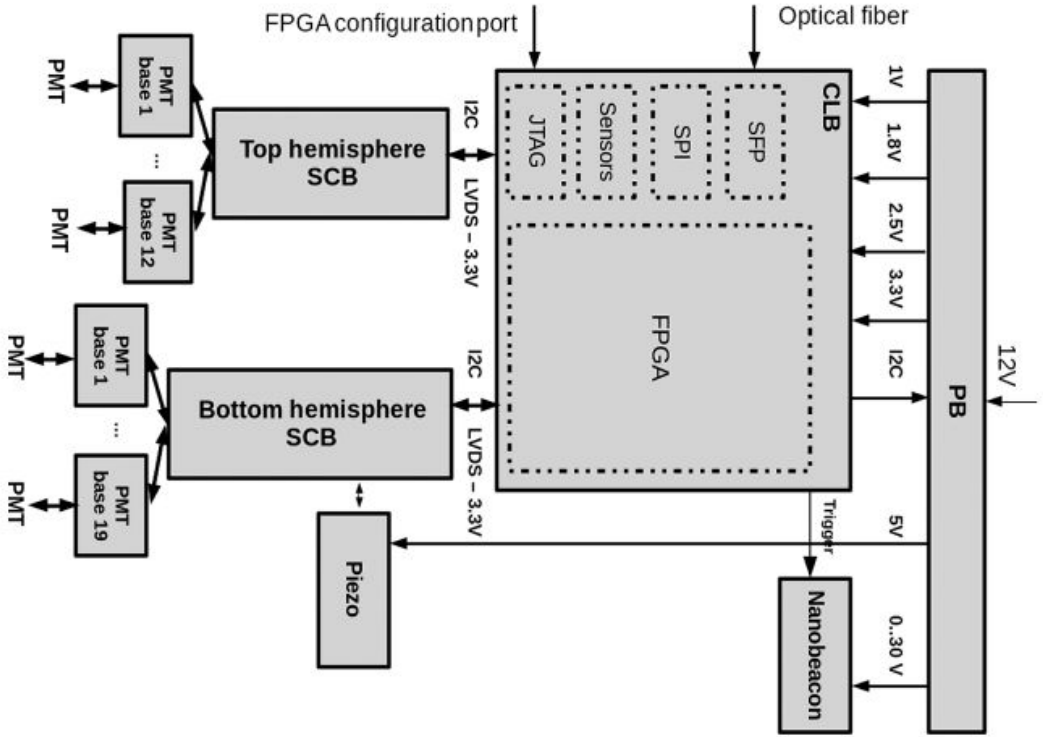
- 1 Power Board (PB)
- 1 Central Logic Board (CLB)
- 2 Signal Collecting Boards (SCB)
- 31 PMT bases



Digital Optical Module Electronics

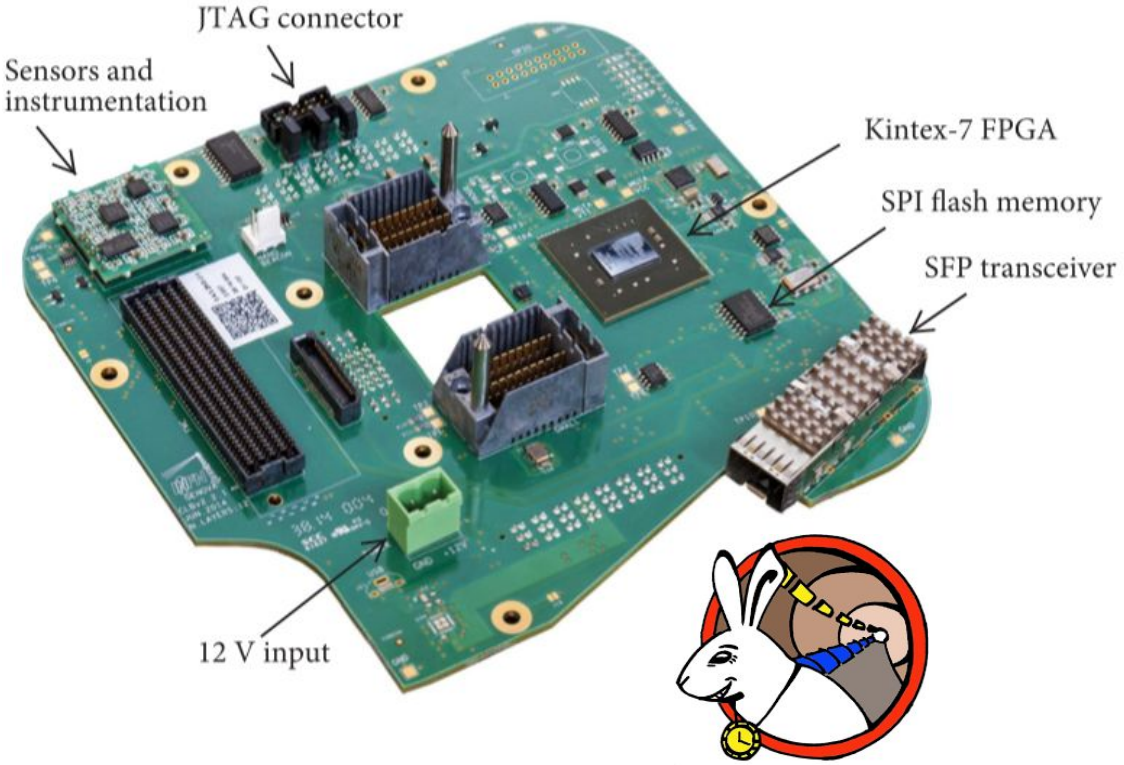
D. Real

- The Power Board converts **12 V** into the voltages needed by the acquisition electronics
- The CLB mounts an FPGA. The acquisition firmware runs on it
- **Communication done via optical fiber**
- The SCBs transfer the PMT signals to the CLB
- The PMT base **digitizes** the PMT signals
- The configuration port only accessible when the DOM is open
- Produced > 1000 electronics boards

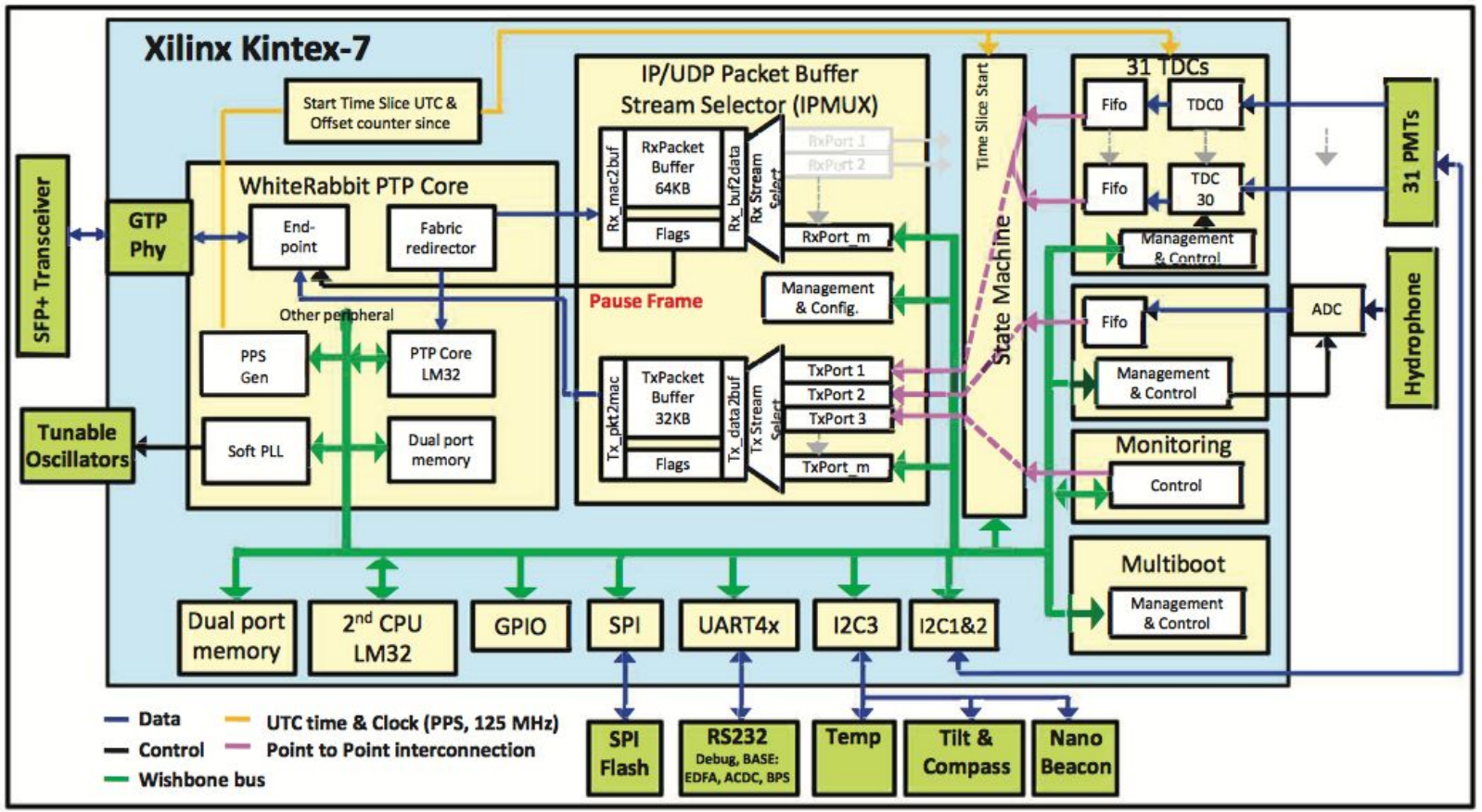


Central Logic Board

- FPGA Kintex 160T. Low power consumption
- SPI Flash 256 Mbytes
- SFP transceiver at 1 Gbps
- Molex connectors for the SCBs
- 12 V input voltage
- Instrumentation: temperature and humidity sensors, compass and inclinometers
- FMC expansion connector
- White Rabbit node

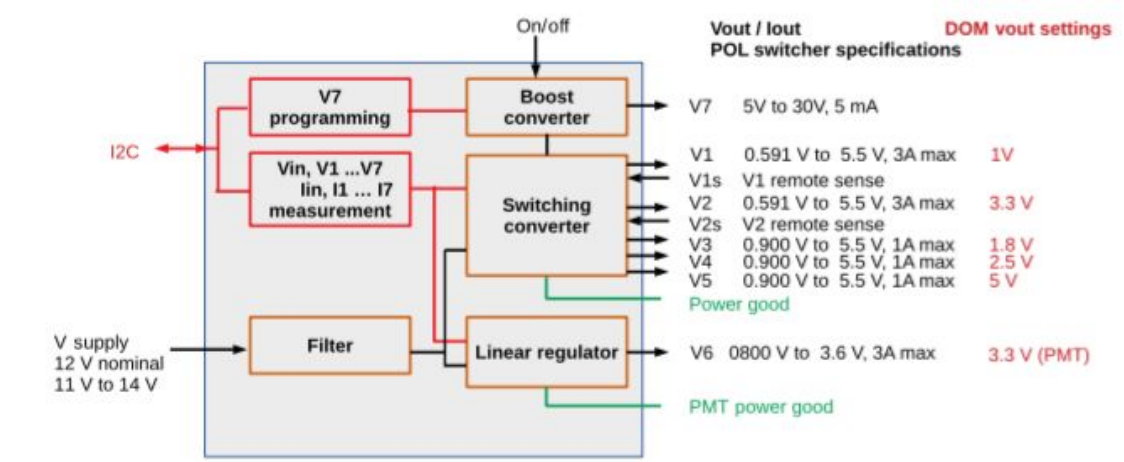


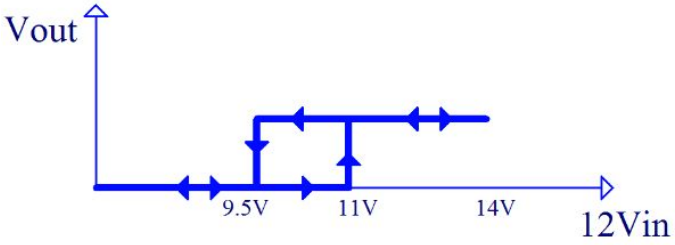
Firmware Architecture

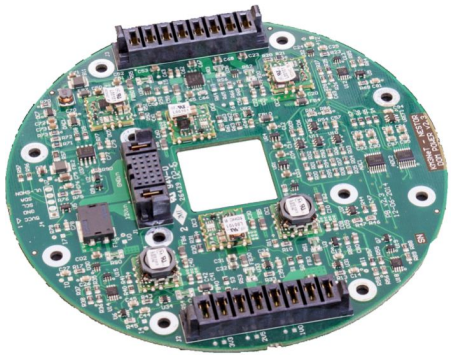


Power Board

- **7 channels**: 1, 1.8, 2.5, 3.3, 3.3 V PMT, 5 V and an **I²C configurable** power supply for the Nanobeacon (5 V .. 30 V)
- **Hysteresis to avoid start up fluctuations**
- Implemented sequencer to switch on FPGA
- Shielded by the cooling block to avoid Interferences

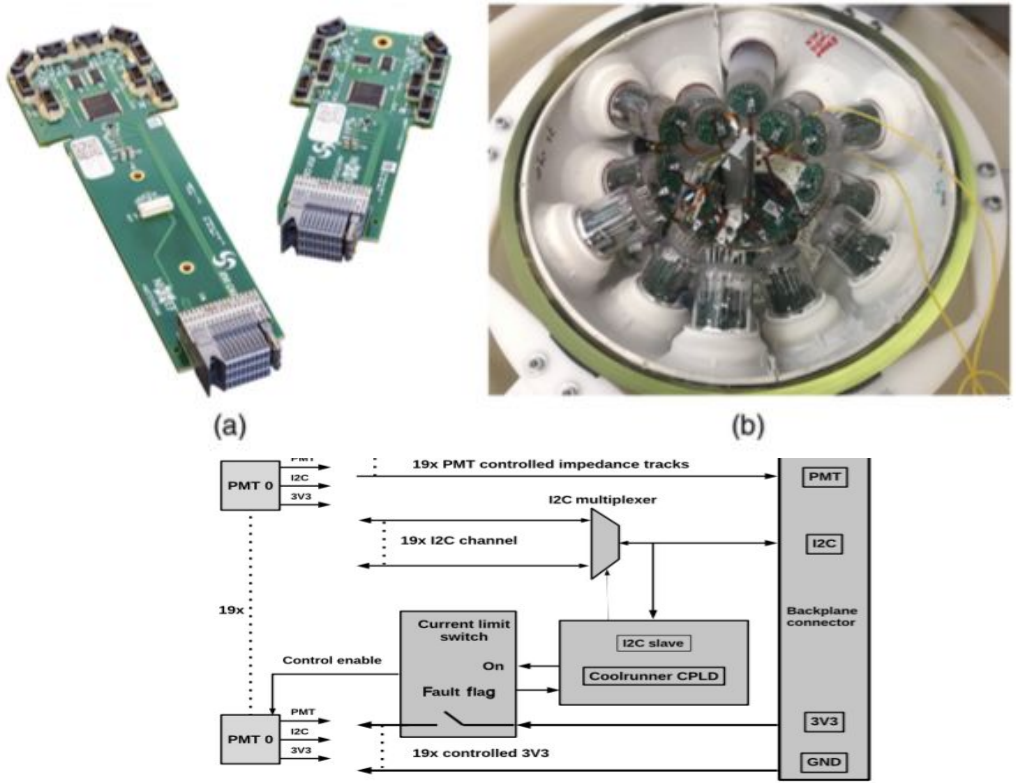






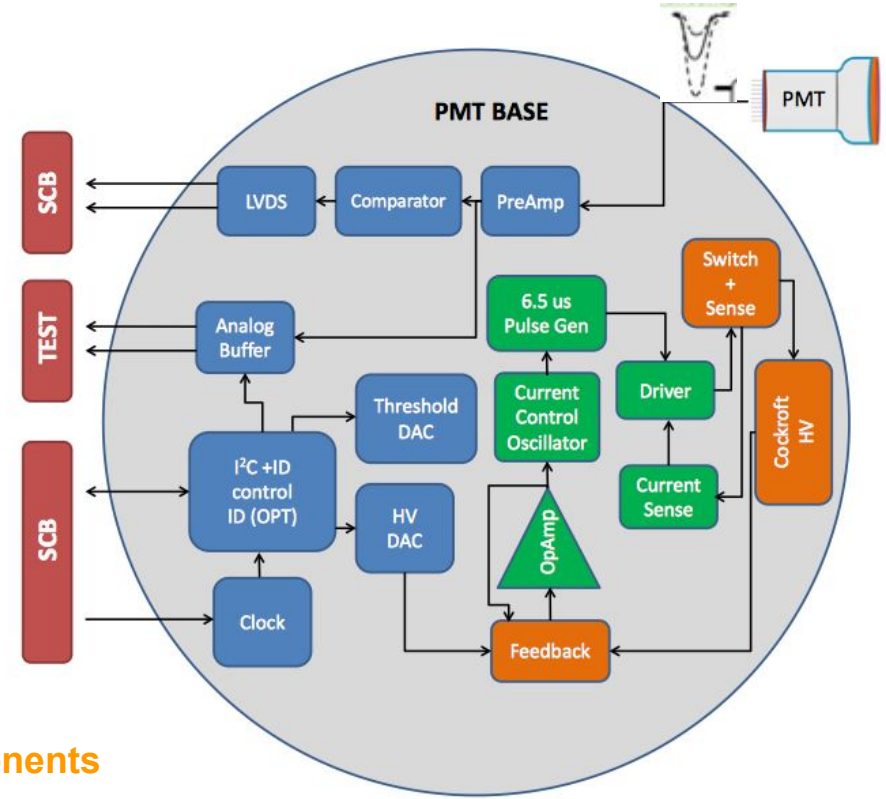
Signal Collection Boards

- **Two SCBs per DOM**: Long SCB with 19 channels and short SCB with 12 channels
- Long SCB in the bottom hemisphere and the short SCB in the superior hemisphere
- Differential tracks with **controlled impedance**
- **I^2C** bus to control the PMT bases
- Power supply to the PMT bases controlled by I^2C



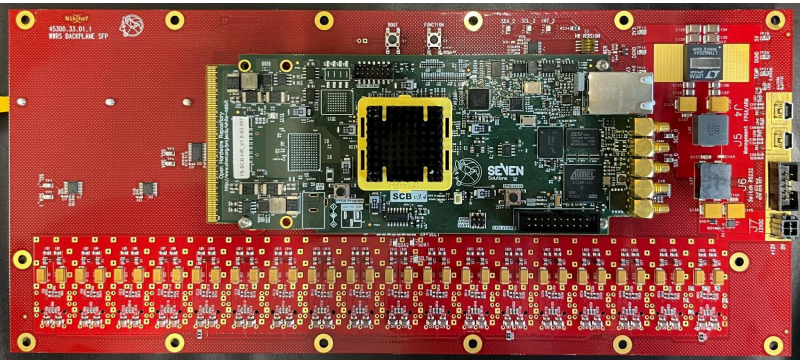
PMT Board

- Turn PMT signals into a differential LVDS (ToT). Active while the PMT signal is over the threshold
- Control vía I^2C:
  - High voltage (-800 V .. -1400 V)
  - Threshold
- 2 ASICs, PROMiS y CoCo
  - **PROMiS:** Preamplifier, discriminator, LVDS output
  - **CoCo** controls the autotransformer of the PMT base and receives the HV feedback
- Create an analogue signal (only for tests)



PROMiS
CoCo
Discrete Components

DU BASE Electronics



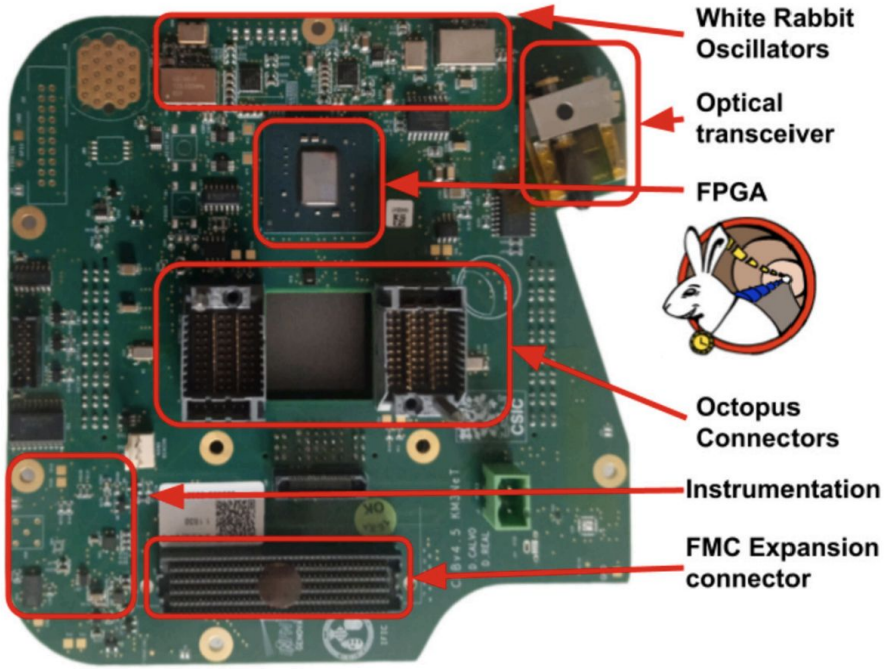
WR SWITCH			
Current Design		KM3NeT Upgrade	
WR SCB			
FIT	MTBF	FIT	MTBF
2937	340483	794	1259445
Chromium board (carrier)			
FIT	MTBF	FIT	MTBF
639	1564945	435	2298850
TOTAL		TOTAL	
3576	279642	1229	813669

290 % improvement in the reliability of the WRS

Mainly due to decoupling capacitors. Better part choice

Latest Developments

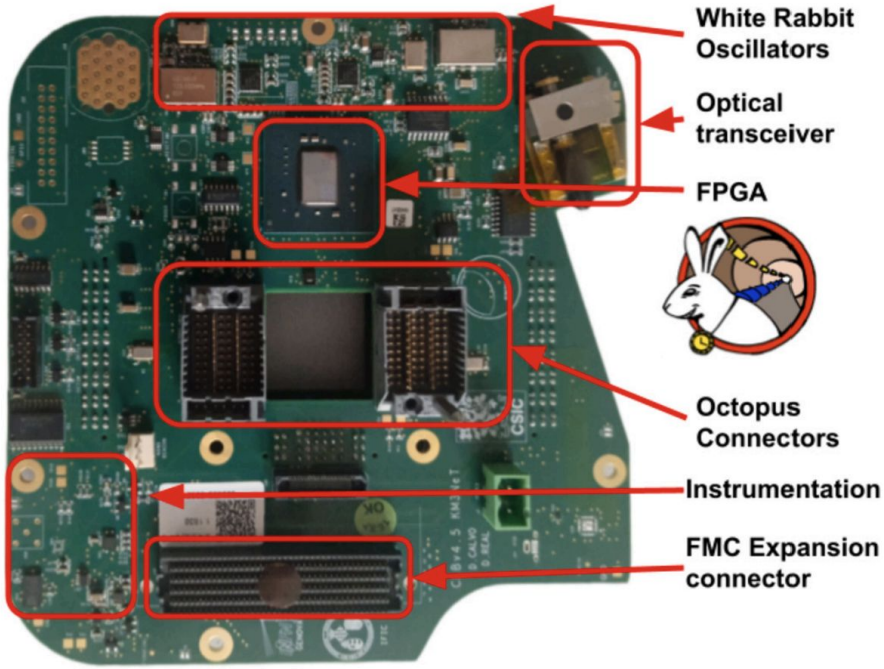
CLBv4



- **Two Flash memories** (Previous version only one. Now logout separated from FPGA image)
- **Glenair optical transceiver** with better reliability
- Hardware Watchdog and new reset scheme
- **Improved clock** schemes with better stability and phase noise
- HALT results very satisfactory (-40 ºC to 100 ºC)

Latest Developments

CLBv4



- **Sensors:**
  1. Temperature (One-Wire DS18B20)
  2. Temperature / Humidity (SHT21)
  3. Compass 1 (LSM303AGR)
  4. Compass 2 (MC6470)
  5. Pressure sensor (LPS25H)
  6. Accelerometer (LIS3LV02DL)
  7. Gyroscope (L3GD20H)
- More than 20% increase in reliability

Latest Developments

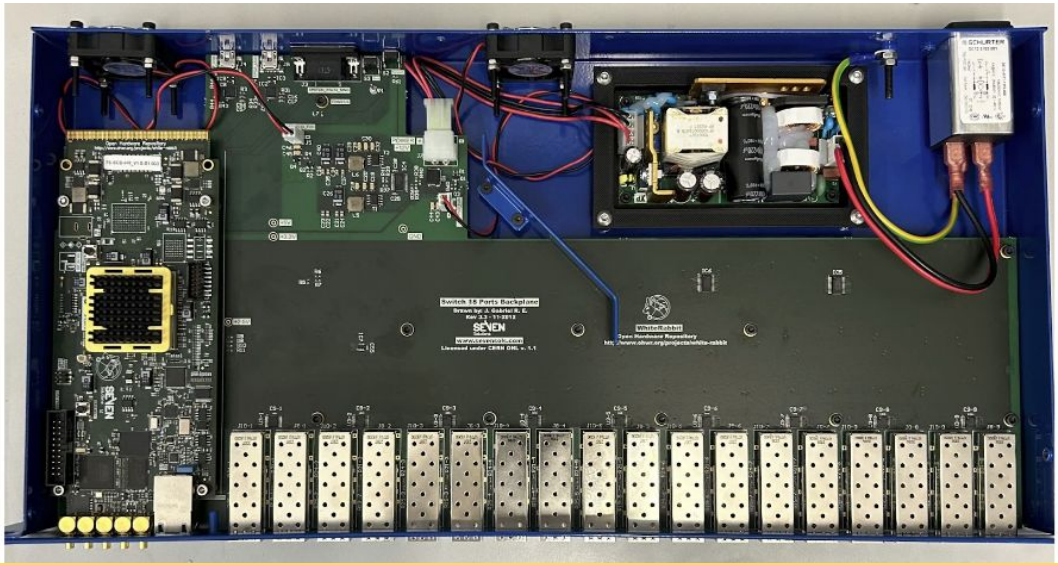
PBv4

- More than 40% improvement in reliability
- Obtaining around 13 % in power saving due to higher efficiency

Volt (V)	Current (A)	Efficiency PB_V2.3 (%)	Total DOM Power V_2.3 (W)	Efficiency PB_V4 (%)	Total DOM Power V_4 (W)
1	0.13	80	~7 W	80	~6 W Saving ~13 %
1.8	0.33	80		80	
2.5	0.33	60		78	
3.3	0.81	65		90	
3.3 PMTS	0.46	90		90	
5	0.10	60		90	

White Rabbit Switch

- High-reliability White Rabbit switch
- 4 protos produced and under evaluation
- To be used in KM3NeT



Reliability

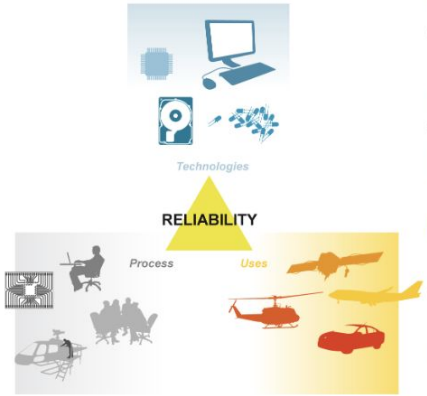
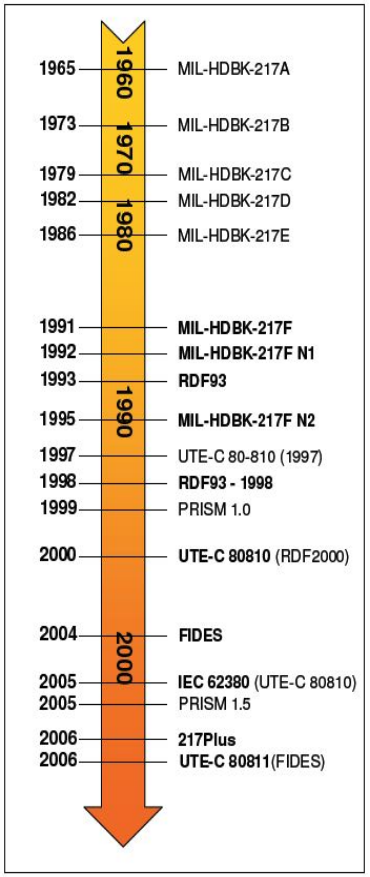


Table 5 FIT and MTTF of the DOM electronics boards of KM3NeT. FIT is defined as the number of failures per 10^9 h.

Product	FIT	MTTF (years)
PMT base	1218	94
Large SCB	157	727
Small SCB	156	731
Power board	1424	80
CLB	417	273



Conclusions

- > 2000 KM3NeT acquisition electronics boards already produced
- Operational in 51 deployed Detection Units
- New Power Board version with higher reliability and higher efficiency
- New CLB version with improved transceiver, additional instrumentation, and improved oscillator system

THANKS