KM3NeT deep-sea cabled network: the star-like layout

R. Cocimano

for KM3NeT Consortium
on the behalf of KM3NeT PPM work package H

VLVnT11 12-14 October 2011, Erlangen

Talk Outline

- KM3NeT Seabed Network Star-like layout
  - Input Data and Main Components
  - Electro-Optical Cable Specifications
  - Power System and Calculation Results
- Primary Junction Box Block Diagrams
- Secondary Junction Box Block Diagrams
- ODI Connector Systems
- Medium Voltage Converter

KM3NeT Seabed Network Layout

KM3NeT is a subsea cabled observatory it is designed to operate for 20 years as permanent infrastructure on the sea-floor providing continuous power and communication to scientific instruments for neutrino detection and deep-sea science.

The TDR describes two possible solutions for the sea-bed network :

- STAR LAYOUT
- RING LAYOUT

This presentation focus on the **STAR SOLUTION** and in particular on the **POWER SYSTEM** and the **TECHNOLOGICAL CHOICES** related to it.

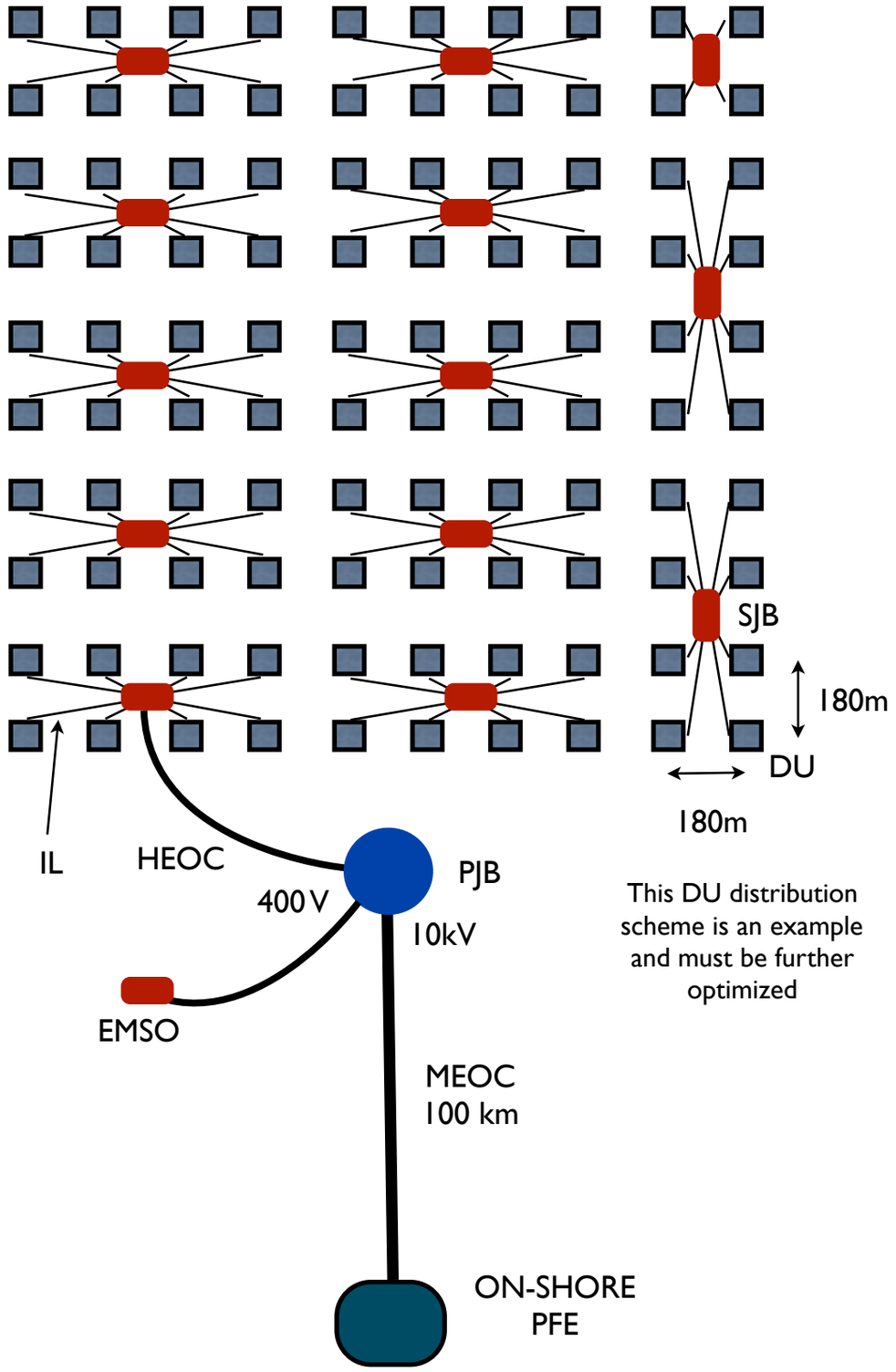
Star-like Network Layout: Input Data

✓ **INPUT DATA for a Building Block (1/3 of KM3NeT)**

- 104 Detection Unit (DU)
- Associated Science
  European Multidisciplinary Sea floor Observatory (EMSO)

- Distance from shore: max 100 km
- Depth: 3500m
- Sea-floor area: ~ 2,6 km^2
- DU matrix distribution on the sea floor

- Power per DU: ~ 350 W
- Associated Science Power: ~10 kW
- Total power requirements offshore: ~ 45 kW



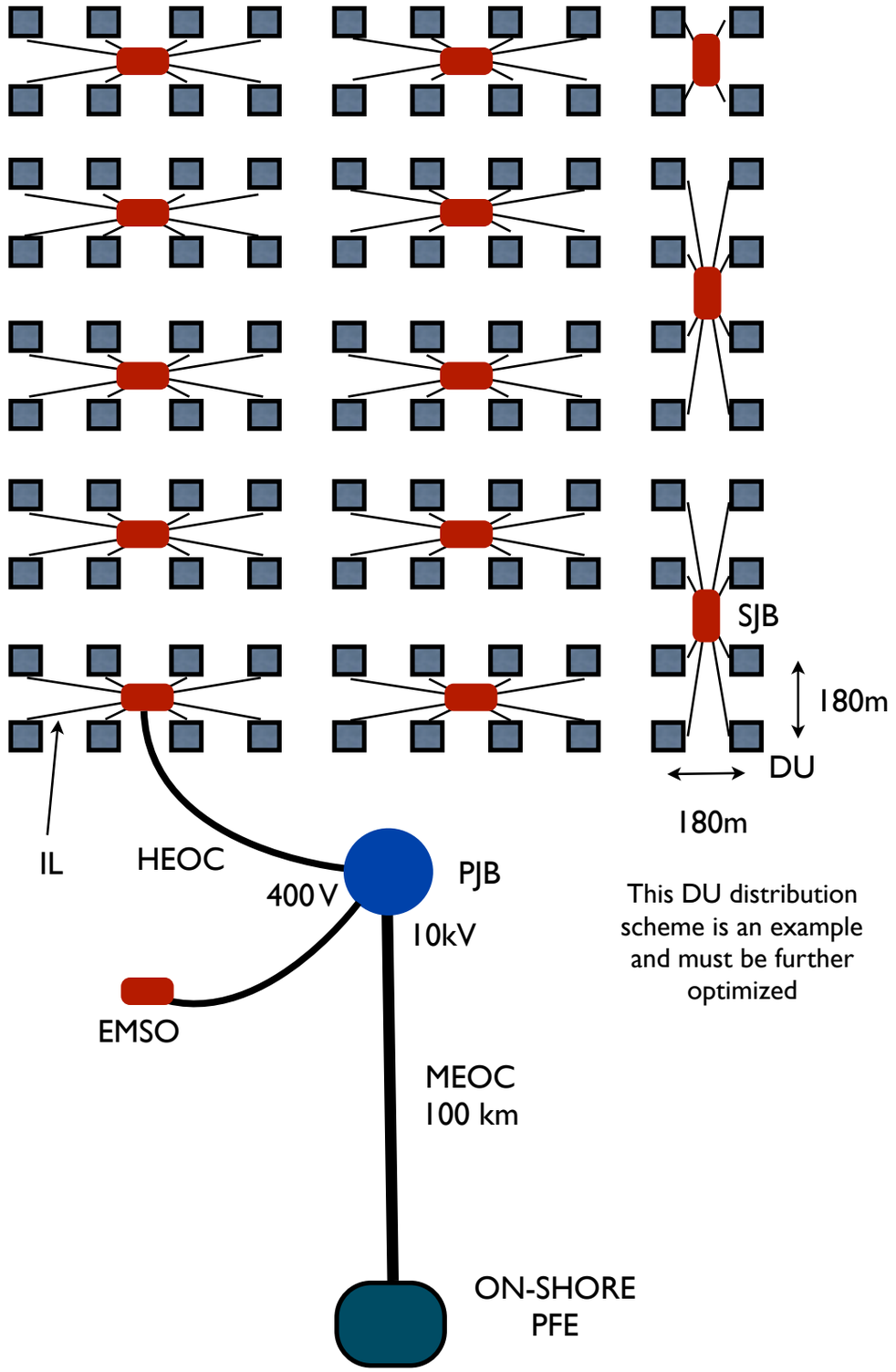
Star-like Network Layout: Main Components

✓**ON SHORE** :

- **Power Feeding Equipment (PFE)** :
  - delivers power to the submarine apparatus
  - Voltage Converter: 400Vac 3 phase / 10 kVdc

✓ **OFF SHORE** :

- **Main Electro Optical Cable (MEOC)**:
  - transmits power and communication to the apparatus
- **Primary Junction Box (PJB)**:
  - steps down the voltage from 10 kVdc to 400 Vdc
  - distribute power and communication to the secondary nodes
- **Horizontal Electro-optical Cables (HEOC)**:
  - connects electro-optically the PJB to the SJB
- **Secondary Junction Boxes (SJB)**:
  - distribute power and communication to 8 DUs
- **Interlink Cables (IL)**
  - connects electro-optically the SJB to the DU

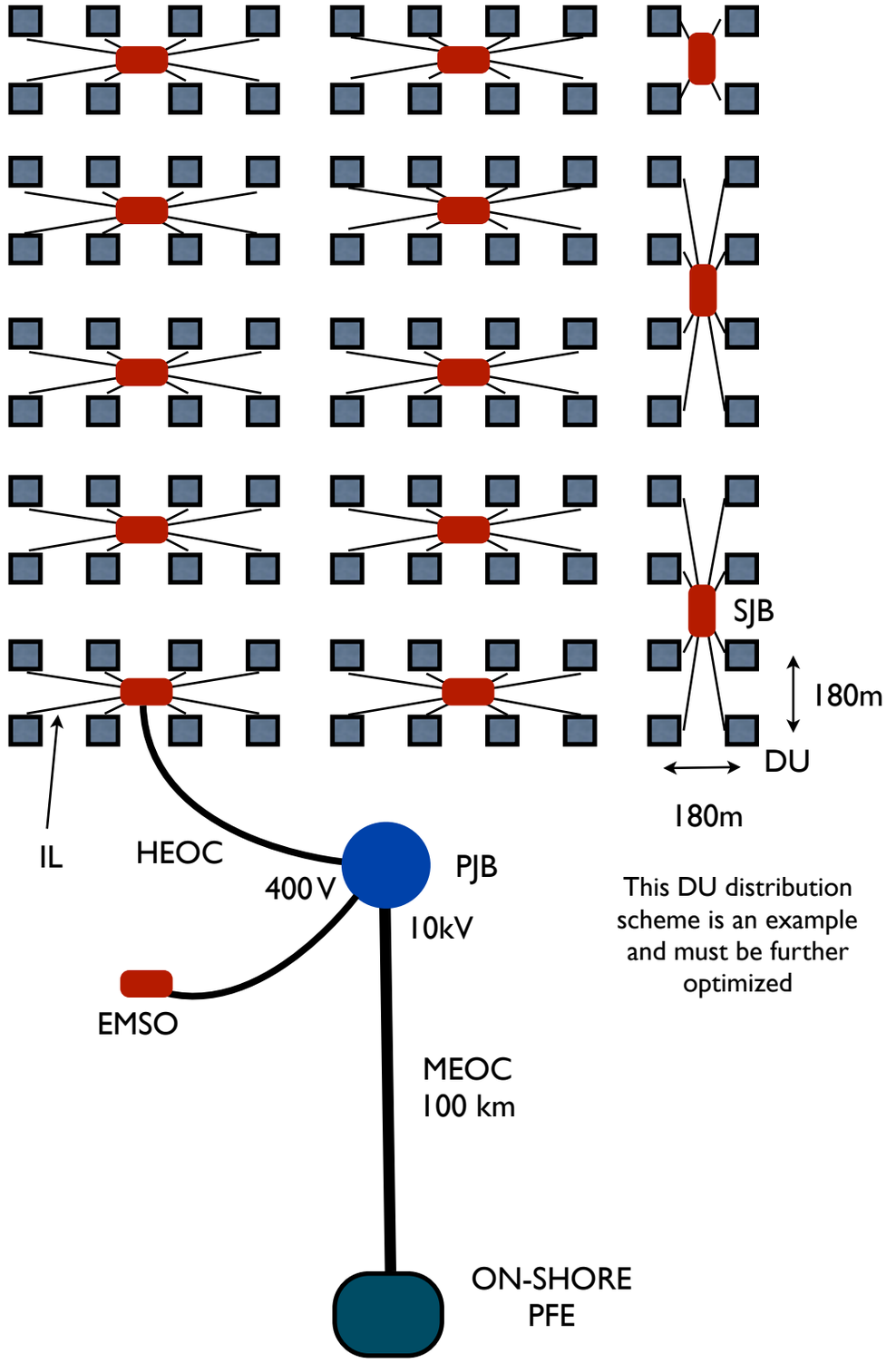


Star-like Network Layout: Power System

✓ **DC POWER NETWORK:**

- **Transmission** Power System (from the shore station to the PJB) :
  DC monopolar @ 10 kV
  - the MEOC copper conductor is energized at -10 KV
  - positive electrode on shore
  - negative electrode off-shore

- **Distribution** Power System (from the PJB to the DU) :
  DC bipolar @ 400 V



Star-like Network Layout: Power Inventory

POWER INVENTORY for a BUILDING BLOCK (104 DUs)

COMPONENT	*POWER / COMPONENT*	*POWER/ BUILDING BLOCK*
DOM	8,7 W	
DU (40 DOMs)	348 W	36 kW
DU local control	10 W	1 kW
SJB internal load	100 W	1,3 kW
PJB internal load	300 W	0,3 kW
Associated Science	10 kW	10 kW
		48,6 kW

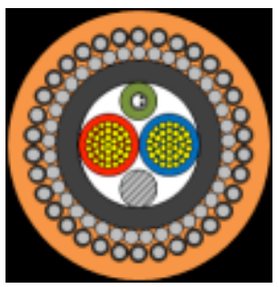
Star Detector Layout: cable specifications

CABLE	ROUTE	LENGHT	COPPER WIRES	QTY	QTY/km
MEOC MAIN ELECTRO OPTICAL CABLE	shore - PJB	100 km	1 copper conductor 1,5 Ω/km	1	100 km
HEOC HORIZONTAL ELECTRO OPTICAL CABLE	PJB - SJB	1000-2000 m	2 x 16 mm^2	14	20 km
IL INTERLINK CABLE	SJB - DU	100-350 m	2 x 16 mm^2	104	25 km
VEOC VERTICAL ELECTRO OPTICAL CABLE	DU backbone (2 VEOC per DU)	880 m	2 x 18 AWG	208	200 km

MEOC

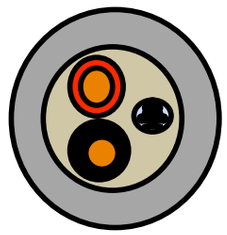
Alcatel·Lucent exans Draka

HEOC & IL



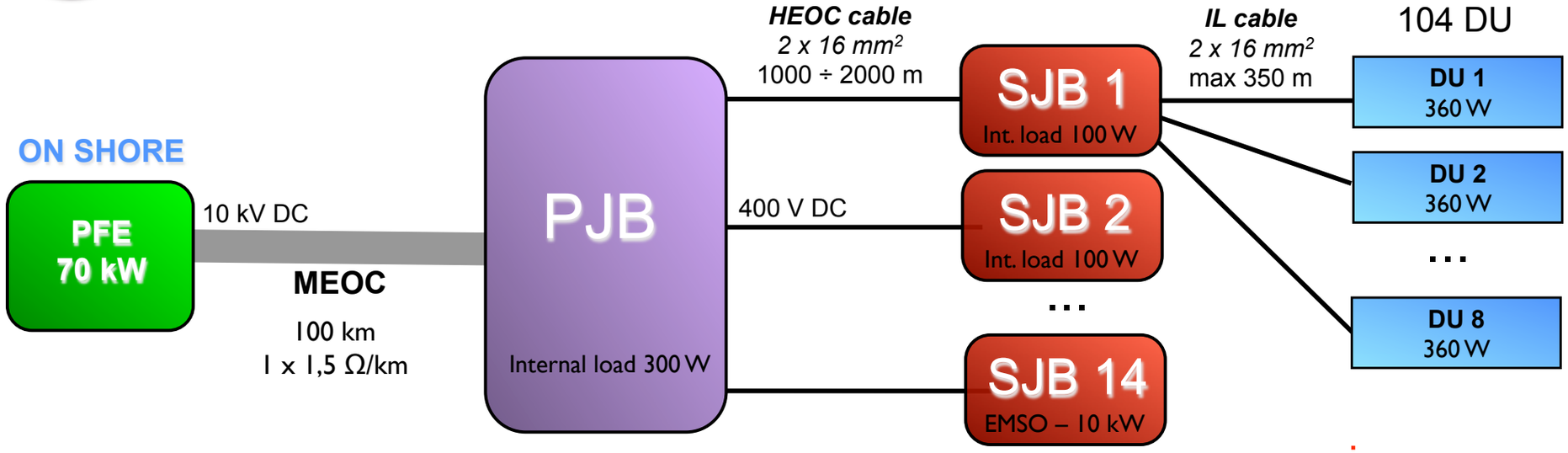
exans

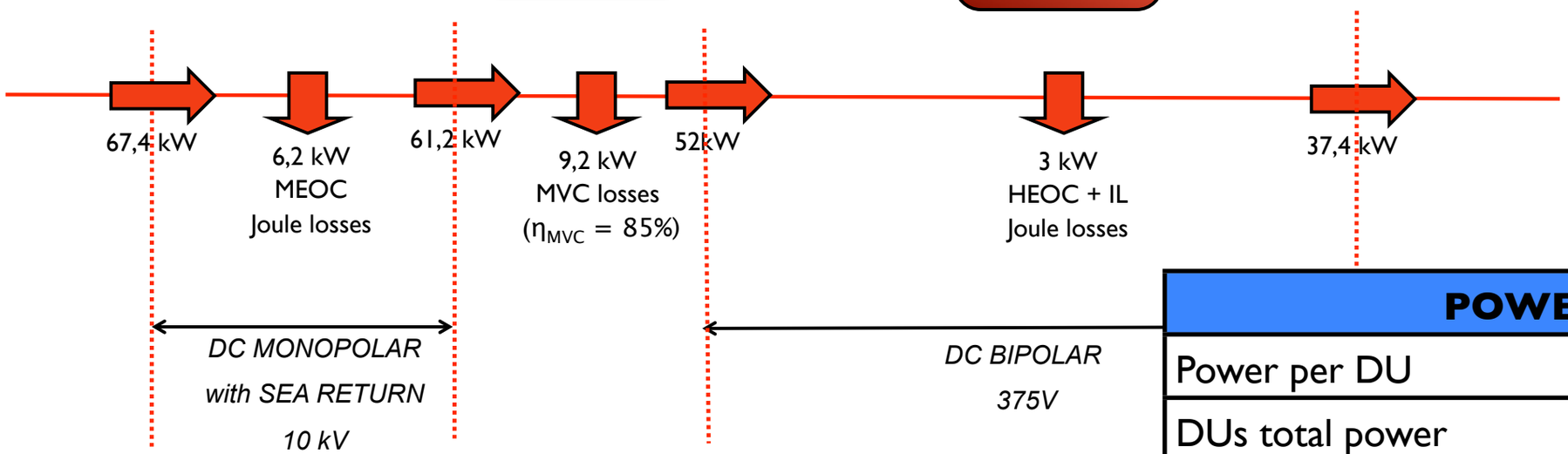
VEOC



NIKHEF

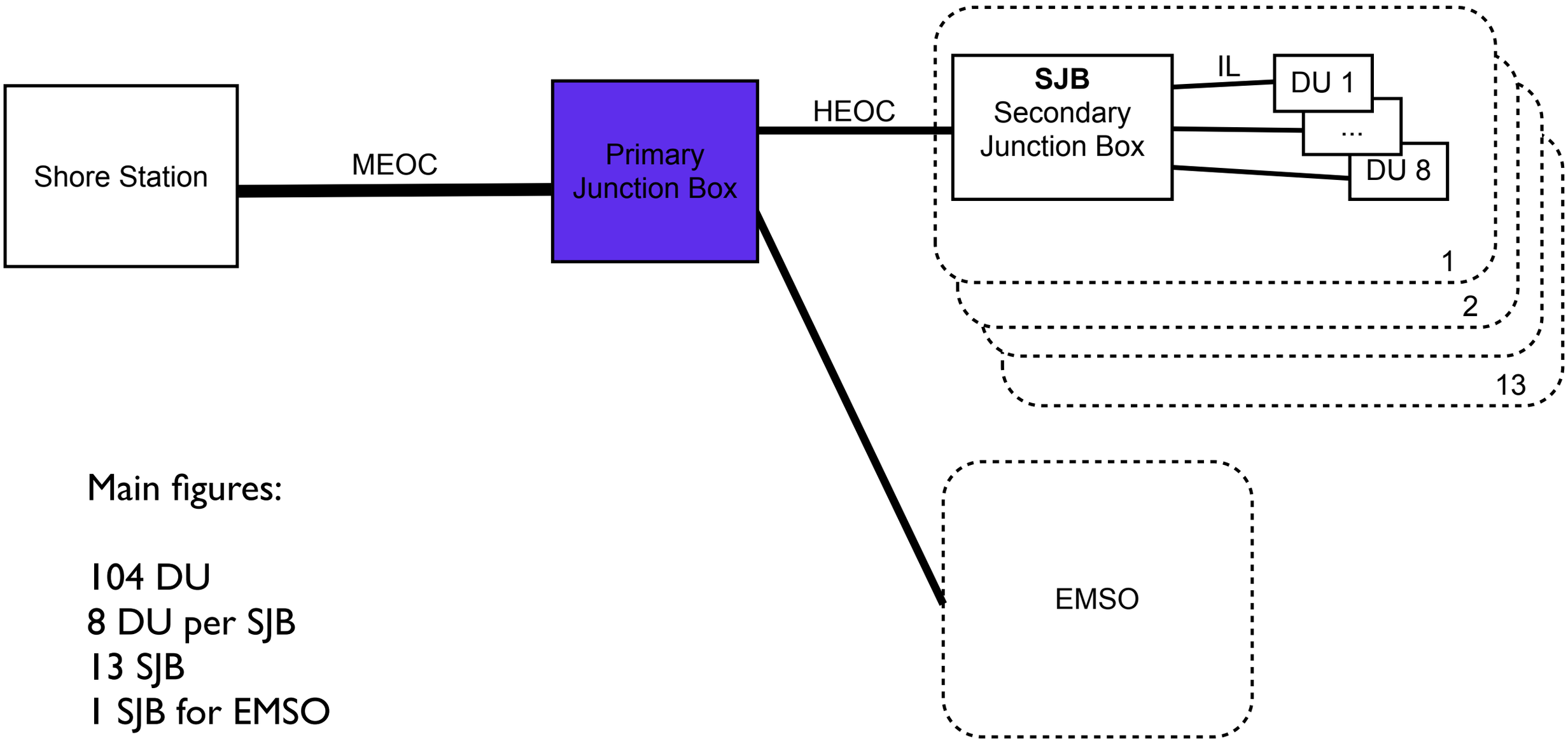
Star Detector Layout: Calculation Results





POWER BUDGET	
Power per DU	360 W
DUs total power	37,4 kW
Associated Science (EMSO)	10 kW
HEOC+IL Joule losses (~6%)	3 kW
Internal loads PJB+SJBs	1,6 kW
MVC joule losses (η= 85%)	9,2 kW
MEOC losses	6,2 kW
TOTAL POWER LOSSES	**27%**
POWER ON SHORE	**67,4 kW**

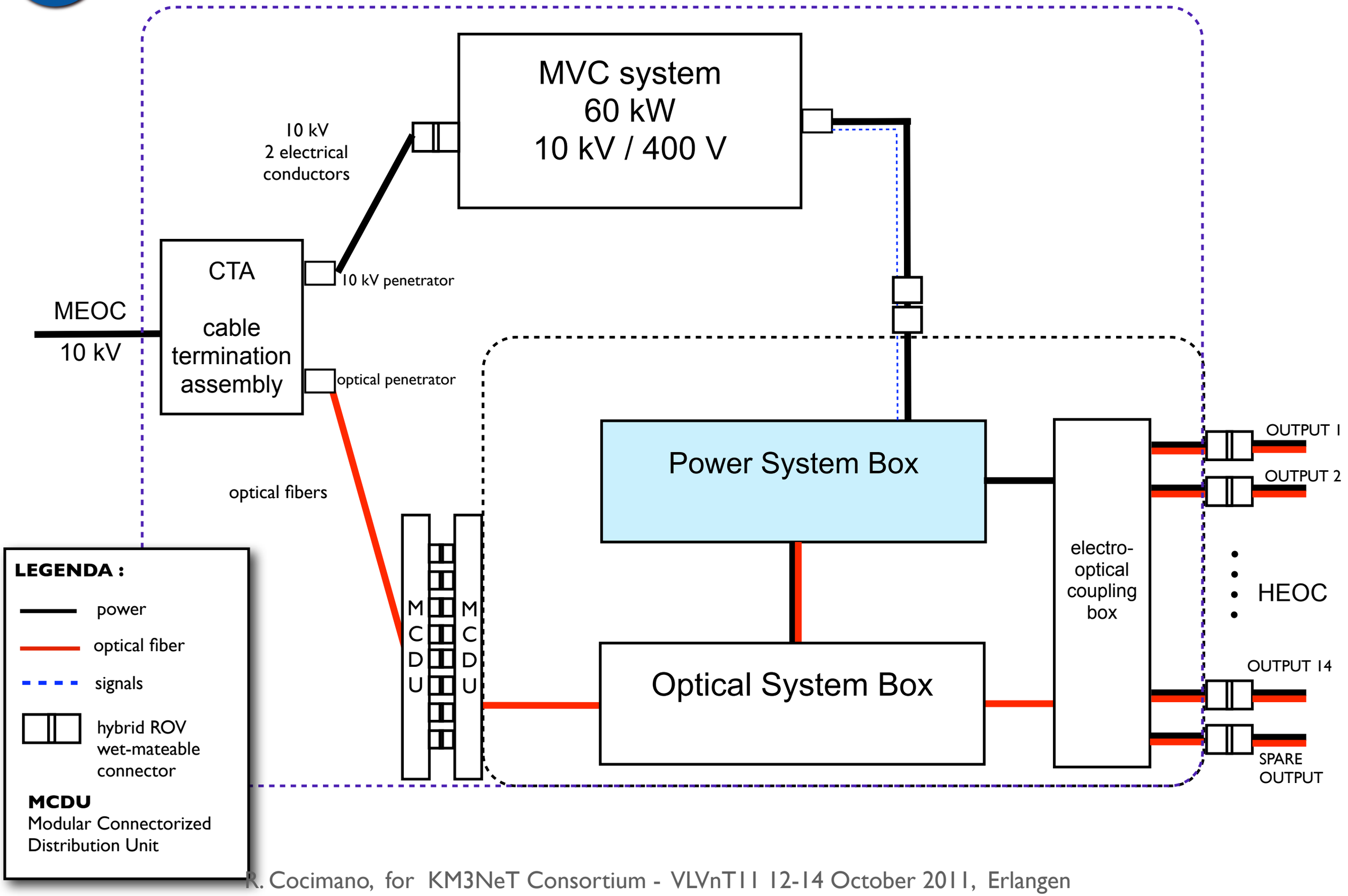
Star Detector Layout: Junction Boxes



Main figures:

104 DU
8 DU per SJB
13 SJB
1 SJB for EMSO

Primary Junction Box: block scheme



PJB - Power System Box

MVC System

Optical System Box

Electro-Optical Coupling Box

INPUT _MVC

Power and slow control from MVC

400 V

2

375 V

2

R 1

OUTPUT_ SJB1

2

R 7

OUTPUT_ SJB7

2

R 13

OUTPUT_ SJB13

2

R 14

OUTPUT_ EMSO

power and conveyed waves slow control

A

V

T

P

H

LV output

power

Power supply 375V/ LV

Conveyed waves to/from SJBs

CAN Bus RS 485/232 Ethernet I2C

Ground Fault Monitor

Analog & Digital I/O

Tx/Rx Copper

f.o. to/from shore

slow control

Tx/Rx

µC

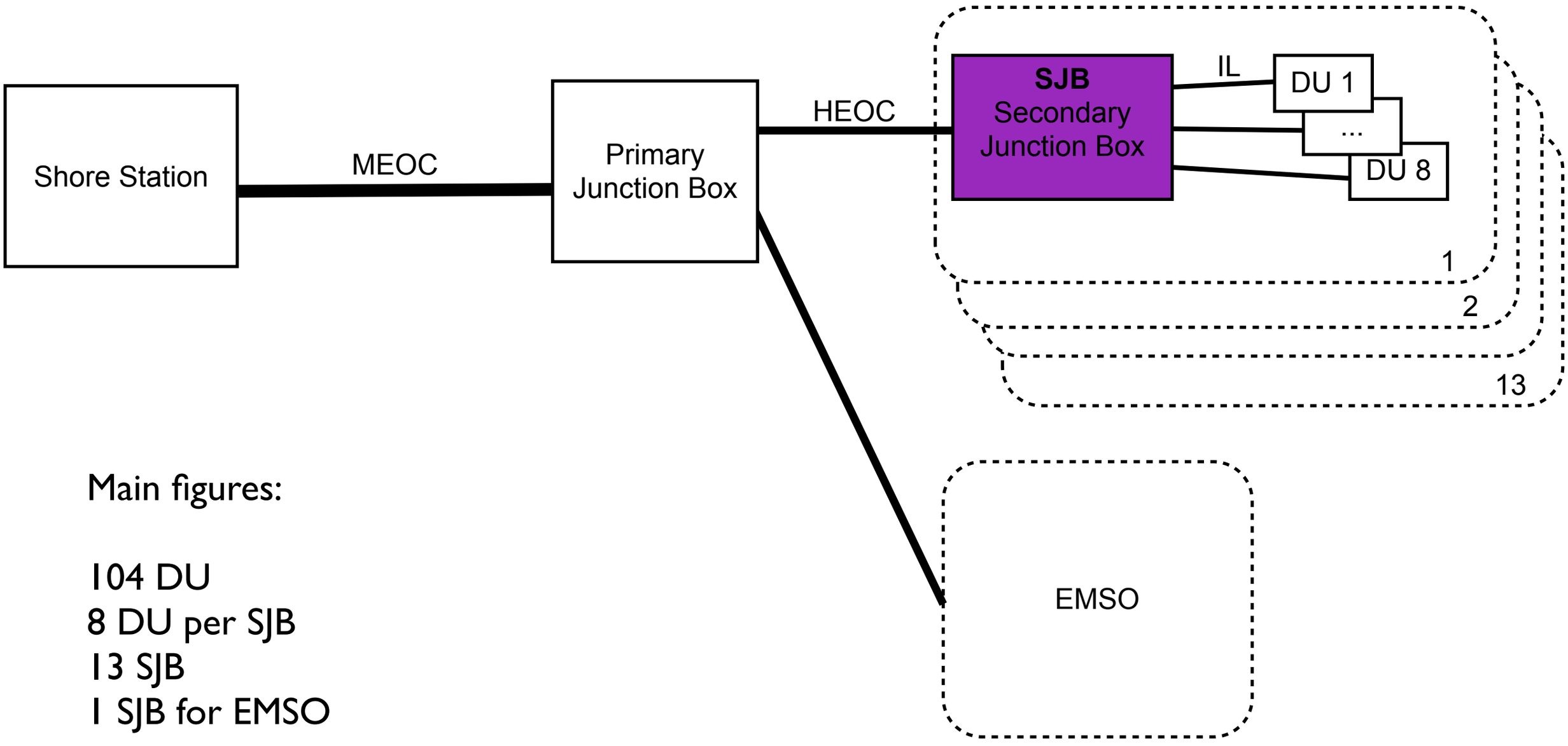
Tx/Rx f.o.

f.o. to/from SJBs

LEGENDA :

- power
- optical fiber
- conveyed waves
- signals

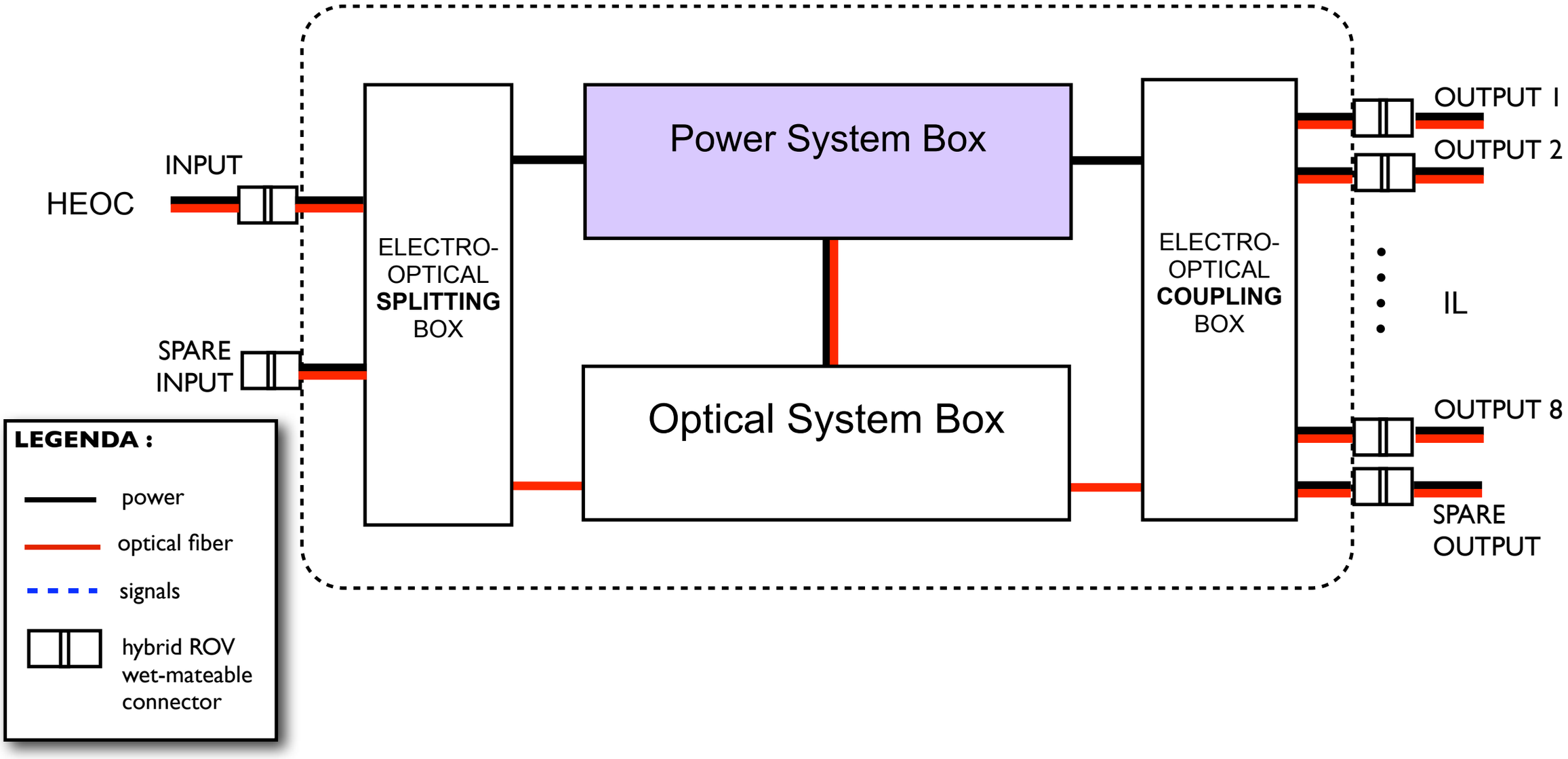
Star Detector Layout: Junction Boxes



Main figures:

104 DU
8 DU per SJB
13 SJB
1 SJB for EMSO

Secondary Junction Box: block scheme



SJB - Power System Box

Electro-Optical Splitting Box

INPUT _PJB

400 V

400 V

2

INPUT _SPARE

400 V

2

power and conveyed waves slow control from PJB

2

A

R 1

OUTPUT_ DU1

R 7

OUTPUT_ DU2

R 8

OUTPUT_ DU8

R 9

OUTPUT_ SPARE

power and conveyed waves slow control to DU

Electro-Optical Coupling Box

V

T

P

H

Optical System Box

LV output

power

Power supply 375V/ LV

Conveyed waves

Tx/Rx Copper

f.o. to/from PJB

slow control

Tx/Rx

RS 485 - RS232 Ethernet I2C

Analog & Digital I/O

µC

LEGENDA :

- power
- optical fiber
- conveyed waves
- signals

ODI 10 kV CONNECTOR

Teledyne ODI
Nautilus High-Power G2

- 3-Circuit, 10 kV_{DC},
- 150 amps DC / 170 amps AC (subsea)
- Max Operational Pressure: 5,000 psi (3,500 meters)
- Mating Force: < 150 lbs
- Demating Force: < 100 lbs
- Material: Titanium
- Design Life: > 25 Years
- designed using Advanced Materials Science & Materials Certification processes
- is being qualified under the guidelines of IEC 60502-2 for medium voltage connectors
- to validate the 25-year performance life
- has demonstrated a reliability level of greater than 99.9% based on accelerated life testing.

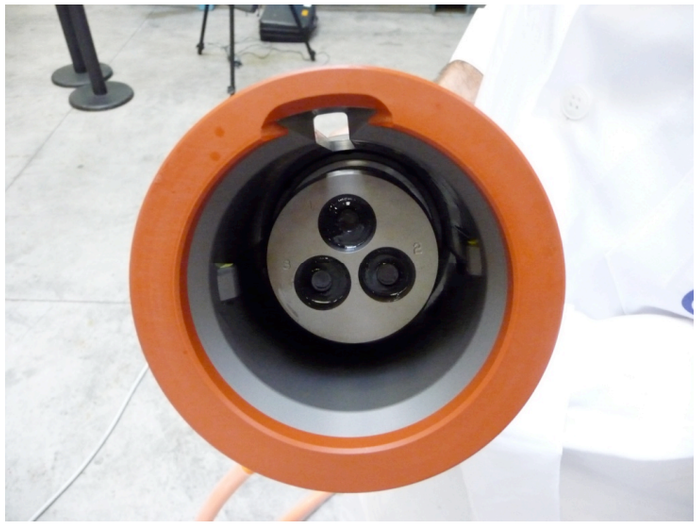
ODI 10 kV CONNECTOR

ODIs 10kV 25 years survival probability based on test results is 0,9998

Several tests have been carried out by ODI in cooperation with Alcatel.

Tests on connector pin did not satisfy Alcatel specification so Alcatel remains cautions about the long term suitability of this connector wet mated.

On the bases of these results, for Alcatel, the connector is qualified for the use in a dry mate configuration



TESTS FOR WET MATE CONFIGURATION ARE IN PROGRESS

ODI MCDU and Wet-mate Connector

TELEDYNE-ODI

Modular Connectorized Distribution Unit

It can provide input connectivity through a variety of sources, such as cable, hose, penetrator

- standardized configurations ranging from 2 up to 8 connector positions.
- 6.5 inch connector spacing
- Stainless Steel or Titanium
- 25 Years design life
- The retrievable MCDU option can be recovered back to the surface for system re-configurations.

TELEDYNE ODI

APC Rolling Seal Connector

wet-mate multichannel optical/electrical hybrid connector

Angled-Physical- Contact (APC)
Max Operational Pressure:
- 10,000 psi ambient
- 5,000 psi differential (bulkhead)

Mating Force: <120 lbs
Demating Force: <100 lbs
Configurations: ROV, Stab & Manual-Mate
Material: Titanium is preferred shell material
Design Life: 25 Years
Number of Circuits: 8 max, optical or electrical
Insertion Loss: <0.5 dB @ 1310/1550 nm
Return Loss: <-45 dB @ 1310/1550 nm
Max Operational Current: 7 amps per circuit
Max Operational Voltage: 700 VAC/1,000 VDC

Medium Voltage Converter:

Alcatel produced a 10 kW, 10kV / 400 V Medium Voltage Converter for submarine application for two projects :

- NEMO: 2 pieces, 1 deployed and working
- NEPTUNE: 6 pieces, 5 deployed and working

As per Alcatel communication they have discontinued MVC product line.

The Alcatel MVC main features:

DC Input Voltage : 5,7kV - 10 kV

DC Output Voltage: 375 V

Power: 10 kW

Input shut down voltage: 5,2 kV

Efficiency @ 10 kV, full load : 87%

Voltage undershoot (10% to 90% step up) @ 10kV: 40 V

Voltage overshoot (90% to 10% step down) @ 10kV: 43 V

Output Ripple Voltage (rms @ 100 kHz) < 1,5 V

Medium Voltage Converter

- An activity of market inquiry finalized to find a new supplier it is on going.
  - ✓ Companies contacted:
  - PBF, OceanWorks, Bruker, Heinzinger

- PFB is a power supply producer, it is interested and It did a feasibility study of a 10 kW/400V

- OceanWorks worked for NEPTUNE and VENUS (Node) and has an experience with subsea cabled network. It is ‘’interested in the development of a 10 kW - 10kV/400V solution in a single stage with firm fixed price and performance guarantees’’.
  - ✓ Activities performed:
  - First contacts with OceanWorks (Canada) Jan. 2011
  - Preliminary technical meeting in Rome in July 2011

- Actual status:
  - the MVC is part of OceanWorks roadmap and now they are willing to develop it
  - PFB intend to subscribe to a future tender
  - the activity of inquiry with more suppliers research in still on going

Conclusions

- Summary of talk:
    - Star-like sea floor network for a KM3NeT building block has been described
    - Power inventory and power calculation results have been presented
    - power distribution and its slow control data routing are described schematically for the PJB and SJB
- Achievements:
    - Cables specifications have been defined
    - Contacts with cable suppliers (Alcatel, Nexans, Draka, JDR) and cable terminations are on going
    - MVC specification are ready
    - Contacts with MVC development companies have started to review the possibilities and scan their interest
- Next Steps:
    - Primary and Secondary Junction Box preliminary design will be carried on

Thank you for your attention