KM3NeT - stringhe

Topics:

- So-called 'KM3NeT Phase 1'
- Introduction/reminder to technical solutions
- Qualification
- Schedule
- Attività in Italia



KM3NeT Phase 1: DOMs and DUs

- 31 DUs (Detection Units) in Phase 1 (2014-2016):
 - 24 DUs in KM3NeT-IT
 - DU-1 and 6 more DUs in KM3NeT-FR possibility to adapt the last 6 DUs in a "ORCA-oriented" layout
- 18 DOMs (Digital Optical Modules) on each DU, spaced by 36 m





600 m

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DOMs

- 31 PMTs of 3" photocathode in a 17" glass sphere
- Optical gel coupling between PMTs and glass
- Reflection rings around the PMTs to increase detection surface
- Electronics, optics for long-range communications and calibration devices installed inside the sphere
- Connection to the rest of the apparatus requires two conductors (+12 V power) and one fibre through a single penetrator



Exploded view of the DOM



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- Long-term tests performed on various prototypes (by ETL, Hamamatsu, HZC) performed at various laboratories (NIKHEF, Erlangen, INFN Catania) with comparable results
- ETL vs. Hamamatsu: larger photocathode area, worse spurious pulse performance
- Pre-production of 600 Hamamatsu pieces (for first line) available
- First batch from production of 15,000 Hamamatsu PMTs delivered
- **REMARK:** new tender to be organized for last 6 DUs



ETL D792KFL

KM3Ne1



Hamamatsu R12199-02



Measurements of PMT time response (example plots)

Electronics

 Custom-made bases to produce HV for the PMTs and to extract the time-overthreshold (TOT) from the analogue signals

 Two signal collection boards ('octopusses') connect the PMTs to the Central Logic Board (CLB)

Main tasks of CLB:

- Control of PMTs and instrumentation (piezo-sensor, nanobeacon, monitoring devices)
- Hit digitization with sub-nanosecond time-stamping from the 31 PMTs
- Long-range communication with shore (with fixed latency): White Rabbit
- A power-board regulates all needed voltages from the input +12V

=> Various rounds of prototyping implemented this year for each board (converging toward marginal changes lately!)



Octopus connected to a set of PMT bases



Internal view of DOM





CLB (left) and power-board (right) in 'mushroom' structure

DOM internal mechanics

- PMT support structure to be produced with 3-D printing design (being) optimized for large production
- Cooling system to provide mechanical support and to efficiently transfer heat from the electronics to the glass sphere – sliding bar allows connection between the two hemispheres before closure
- Tray added inside DOM for fiber management
- Custom-design penetrator assembly performed at NIKHEF so far. Production to be outsourced (first batch being ordered).





Fibre management tray

DU mechanics

- Mechanical structure of the string based on two dyneema ropes, anchored on sea floor and kept taught by commercial top buoys (plus DOM buoyancy)
 - Robust and stiff arrangement
 - DOMs keep the correct attitude
 - String dynamics under control
- the VEOC (Vertical Electrical-Optical Cable) connects all DOMs to the DU base the VEOC is an oil-filled pressure-balanced hose equipped with 18 optical fibres (one for each DOM)
- DOM collars keep the DOMs in their positions
- A Break-out-box (BOB) is the interface between a DOM and the VEOC
 - Very simple structure hosting fibre splices and a DC/DC converter
 - A short cable (BEOC BOB Electrical-Optical Cable) connects the BOB to the DOM penetrator



VEOC

DU installation

• DU is packed on launcher vehicle (LOM) and installed on the anchor

• After deployment on sea bed, unfurling is done by operating an acoustic release

• LOM and acoustic release are recovered after operation



Arrangement on LOM (detail)



DU deployment



DU unfurling



Development plan

Staged process: • PPM-DOM • PPM-DU • Installation tests • Onshore qualification (leading to DOM-0) • DU-1 • Being prepared for this fall

Development plan

PPM-DOM

• Single, complete DOM with long-distance communication with shore

- Installed on instrumentation line of ANTARES at 2500 m depth in April 2013, operated smoothly since then
- Paper recently submitted

PPM-DU

- Reduced-size DU equipped with 3 DOMs
- Equipped with VEOC, deployed with LOM
- Installed at Capo Passero (3500 m depth) on 7 May 2014
- In smooth operation since then

Installation tests

- Various tests performed in sea and laboratory
- New deployment campaign performed in June 2014

Onshore qualification (incl. DOM-0)

- Electronics and optical system to be qualified onshore
- Environmental and pressure tests on critical components



PPM-DOM during deployment



DU-1

Final validation of all technical solutions will come with operation of first line

PPM-DOM

• Ready since fall 2012, deployed on April 16 2013 and operated smoothly since then

• Precious experience:

proof of concept
bench-mark of integration
experience in calibration, operation,
data taking and analysis
Very interesting results (rates, hit multiplicity, etc.
Paper submitted

• No proof for:

- **o String mechanics, VEOC and installation**
- **o** Final electronics and optical system





TOT control via HV tuning



Time difference in signals from a pair of PMTs



Coincidence rate vs. difference in PMT orientation

PPM-DU

- DOM1 and DOM2 equipped with ETL, DOM3 equipped with Hamamatsu PMTs
- Two top spheres for buoyancy
- Bottom section of VEOC built by putting together two sections of 36 m
- Jumper for connection to sea-bed infrastructure installed on anchor
- Construction in various laboratories, integration at NIKHEF, calibration in dark room at Marseille



Integration of PPM-DU (sel. pictures)



Lifting test of the anchor



Base container under test



Three DOMs and base container integrated with VEOC



Front and rear view of the shore station rack at NIKHEF



PPM-DU arranged in transportation box

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Activities at CPPM



Laser and pattern generator used in dark room tests



PPM-DU with fibre network for calibration in the dark room







Installing the LOM on loader with fork lift (overhead crane *h.s.* at that time) s the INEN referees. Rome, 25, July 201



Loading the LOM

PPM-DU installation

- Performed with Nautical Tide, sailing from Malta 0
- **Deployment assisted by ROV** •
- Line positioned and oriented thanks to ROV 0
- Line position: 60 m from tower, 84 m from CTF (1 m off nominal) 0
- **Connection performed nicely at first attempt** 0
- Inspection of unfurled structure: everything in good order 0
- Acoustic release frame and LOM recovered directly from the ship 0





Last functional test in Malta

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Jumper arranged





ROV orienting the anchor of the PPM-DU



PPM-DU onboard the Nautical Tide

Connections on CTF

Status of PPM-DU

Communications ok

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- All PMTs active, except channel 14 of DOM2 (damaged during DOM integration) and channel 27 of DOM3 (disabled because of high rates and strange behaviour induced in the full DOM) – see next slide
- All devices operational except tiltmeter of DOM3 (ok at NIKHEF, not tested at CPPM, found *h.s.* since first test in the sea)



Measurements from piezo-sensors

Status of PPM-DU: PMTs

- ToTs and inter-PMT time offsets compare nicely with shore calibrations
- Inter-DOM time offsets seem stable (and understandable)
- Attempts to perform cross-calibrations with the tower
- 3-DOM coincidence events: muons! (investigations ongoing)





Installation tests

Various activities performed in the past years:

- First campaigns in Dec 2009 and Feb 2011: Validate the conceptual design and provided suggestions for improvements
- April 2013 @ Motril (Spain): 10 days for five deployments using two LOMs *Positive outcome, but:*
 - DOM penetrator gluing procedure wrong (led to leaks)
 - Cable management on the LOM to be improved
 - Rope spreading bars to be redesigned
 - Strengthen clip to hold VEOC to rope

Remark: full VEOC NOT tested because of penetrator problems

Hence:

- Dry test in laboratory to check mechanical components and close inspection of DOM release (Done at CPPM, Dec-2013)
- New sea campaign launched to test complete process with full mechanics and VEOC (performed 6-11 June 2014)



Clips holding extra-loop of VEOC on LOM

Done
 (& tested with the PPM-DU)

Installation tests at Motril, June 2014

- Installation at ~1000 m depth offshore Motril, Spain •
- Two LOMs prepared with full-size mechanical models of DU •
- **VEOC** equipped with electrical and optical loops for monitoring cable integrity 0
- Spheres loaded so as to reproduce weight of DOMs •

Main results:

- **VEOC** broken during unfurling of first unit problem ascribed to VEOC clips being too loose
- Unfurling of second structure performed after securing clips with tape no • problem for VEOC
- Small water leak into one sphere (ascribed to hemisphere sealing) ۲
- Post-recovery investigations ongoing ۲



Taped clips on second unit



ROV inspection of unfurled structure KM3NeT meets the INFN referees, Rome, 25 July 2014



Preparing deployment

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Onshore qualification

- Reminder: PPM-DOM and PPM-DU equipped with prototype electronics and optical system
- Coordinated activities are ongoing for validation of final electronics and optical system



Wavelength tuning of the SFPs

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Angular acceptance of PMTs



Transfer function of charge vs. TOT



Light collection ring tests





Set-up (left) and test results (above) for White-Rabbit validation

Recent progress

- Test bench set up for optical system for KM3NeT-FR, to be used later for KM3NeT-IT
- Simulations ongoing of optical and power system for KM3NeT-FR and KM3NeT-IT
- Optical system design finalized, choice of SFP made
- White Rabbit upgrade implemented for usage inside KM3NeT White Rabbit communications established
- Electronics extensively tested final versions of electronics reached
- Test scenario of PMTs and electronics defined tools under development

Remarks concerning integration:

- PMT tests to be done at Naples and Erlangen
- DOM integration to be done at Naples, Catania, NIKHEF, Erlangen nominal speed at regime 5 DOM/site/week
- DU integration to be done at NIKHEF and Marseille plus possibly Catania nominal speed at regime 1 DU/site/month

Milestones (dettate dai vincoli in Francia e Italia, in particolare il PON)

- Installation of MEOC and node at KM3NeT-FR in fall 2014
- Installation of 2 JBs at KM3NeT-IT in fall 2014
- [Installation of (at least) two towers at KM3NeT-IT in fall 2014]
- Qualification completed, PRRs performed in September 2014
- Production of first set of 72 DOMs in October-November 2014
- DU-1 ready by end 2014
- Mass productions of DOMs and DUs from January 2015
- Installation of DU-1 in France in early 2015
- Installation of first set of DUs at KM3NeT-IT in spring 2015
- Installation of new CTF and 2 additional JBs at KM3NeT-IT in spring 2015
- Installationg of Phase 1 completed in 2016

Principali attività in Italia

- Bari: Technical Coordinator (Marco Circella); risk analysis; base container; modello meccanico e disegno generale della linea; prototipaggio
- Bologna: coordination del DAQ (Tommaso Chiarusi); DAQ system; elettronica di test
- Catania: integrazione dei DOM e, in prospettiva DU; test su PMT e integrazione DOM
- Genova: elettronica (CLB)
- LNS: coordination di calibrazione (Giorgio Riccobene) e power system (Rosanna Cocimano); coordination del WG di v-astronomy (Rosa Coniglione); sistema di alimentazione delle stringhe; acustica; installazione stringhe; shore station; produzione di una varietà di componenti
- Napoli: installazione delle basette sui PMT; test dei PMT; integrazione dei DOM
- Pisa: ancora
- Salerno: DB e DAQ control
 - + data analysis, simulations: tutte le sedi (in particolare BO e LNS)
 - + Mauro Taiuti presiede l'Institute Board
 - + Piera Sapienza presiede il Conference and Outreach Committee (COC)
 - + Annarita Margiotta è membro del COC, Paolo Piattelli del Publication Committee

+ Emanuele Leonora e Pasquale Migliozzi partecipano al Technical Coordination Team (in fase di definizione)