

Calibration Methods and Tools for KM3NeT

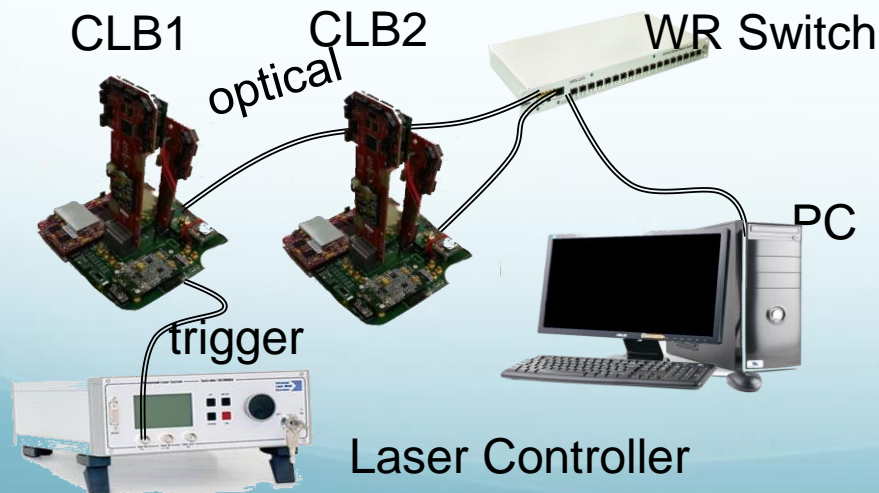
V. Kulikovskiy on behalf of the KM3NeT collaboration

Contents

- DarkBox (acceptance and calibration of all PMTs before assembly into DOMs)
- GreenBox/BlueBox (acceptance and calibration of the DOM before integration in a DU)
- Time synchronization
- Acoustic positioning
- Calibration Unit (seawater properties measurement, part of the system for acoustic positioning of DOMs and interline time calibration with laser).

PMT qualification - DarkBox

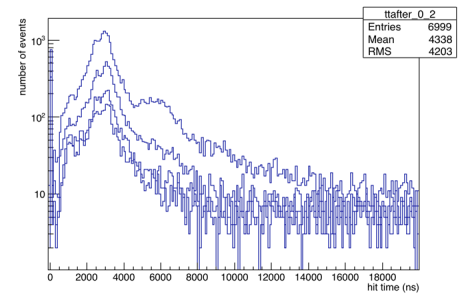
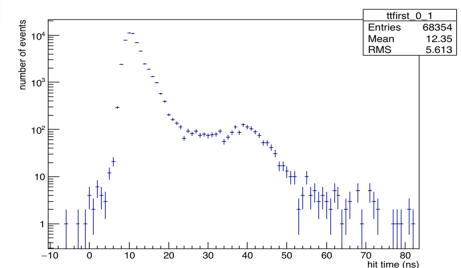
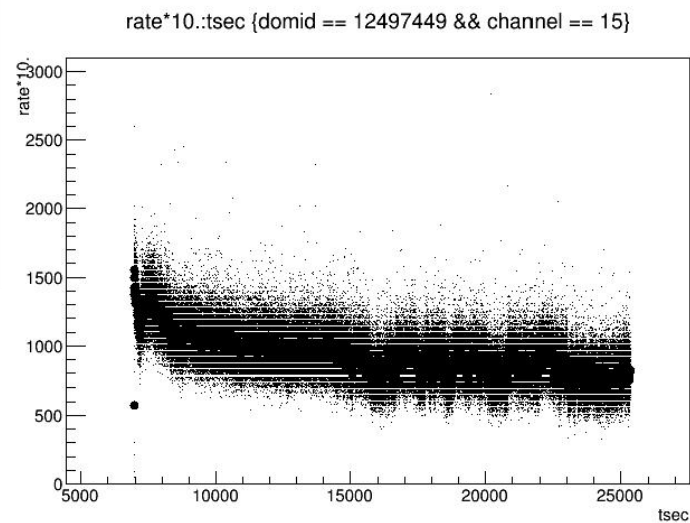
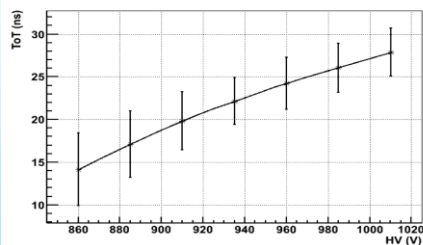
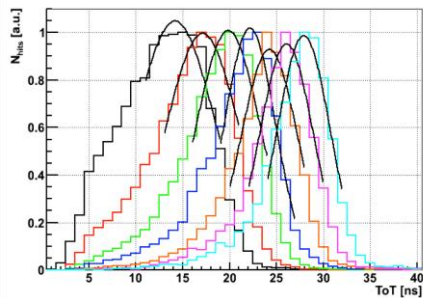
- Simultaneous tests of 62 PMTs (2 DOMs).
- Electronics + DAQ reused from the final project.
 - 2 CLBs synchronized with White Rabbit Switch.
 - Octopuses + long cables for the PMT connections.
 - Laser
 - triggered using the DOM nanobeacon trigger (synchronous with CLB clock)
 - Splitter for 62 channels with the same fiber length and similar power output.



See talk of Carlos Napoli

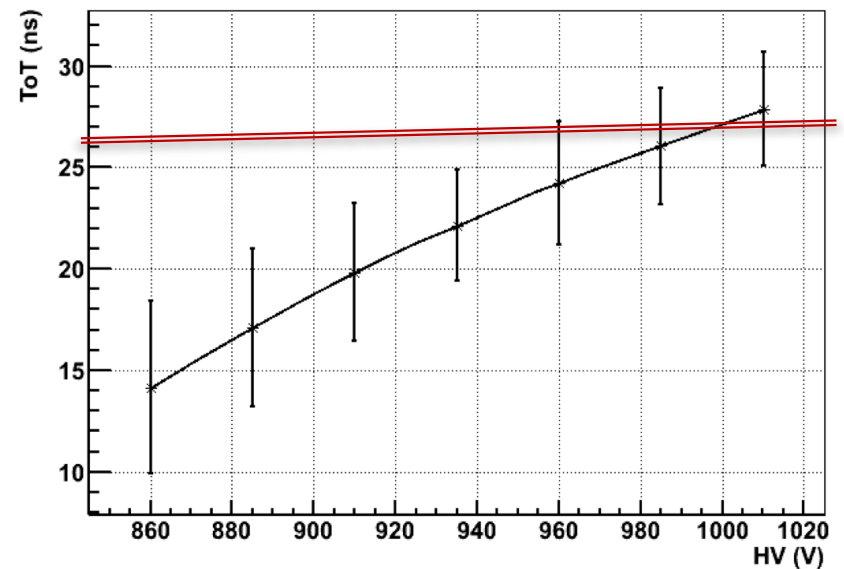
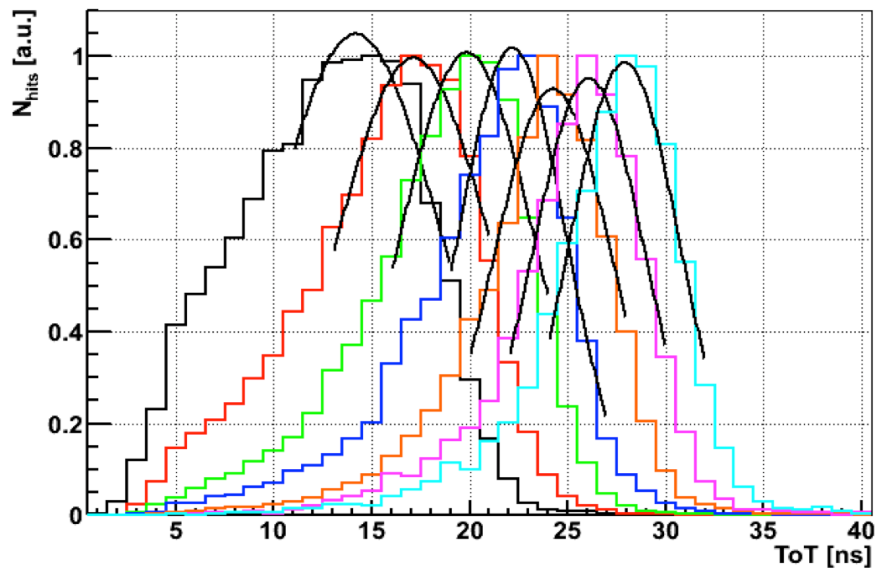
PMT qualification - DarkBox

- PMT calibration and qualification:
 - HV tuning to have fixed Time over Threshold time (ToT correlates with number of photoelectrons)
 - Darkening (>8 h), dark rate measurement.
 - Transit time: TT peak, TTS (PMT delay + base digitisation)
 - Spurious pulses (prepulses, delayed, afterpulses type II)
- DB upload – PMT passed qualification are ready to be used in the DOMs (precalibrated).



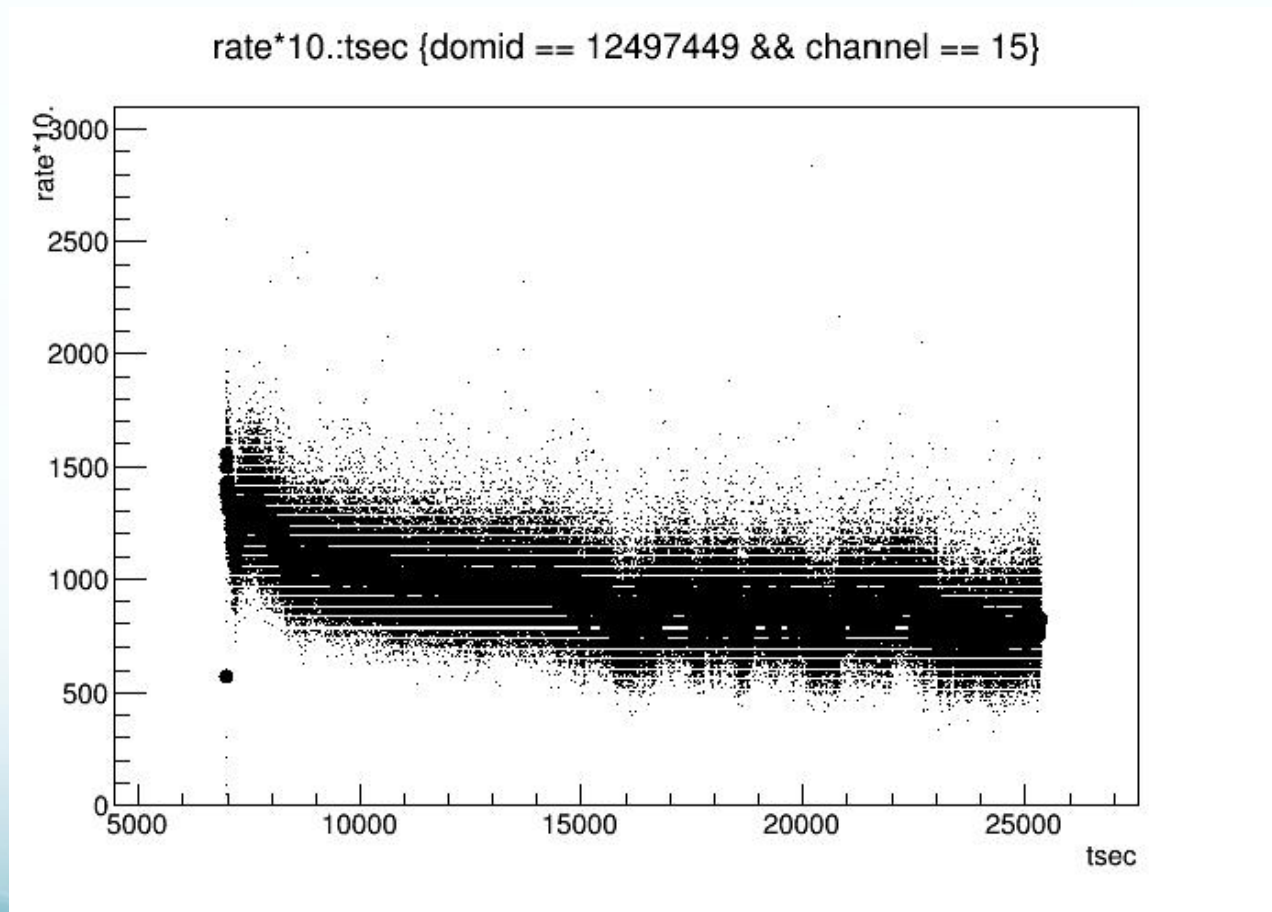
HV tuning

- Dynodes voltage ratio used for KM3NeT is not the default option – HV tuning is needed to be performed.
- Tune HV to have 26.4 ns ToT mean (the value obtained from the PMTs with tuned proper gain).



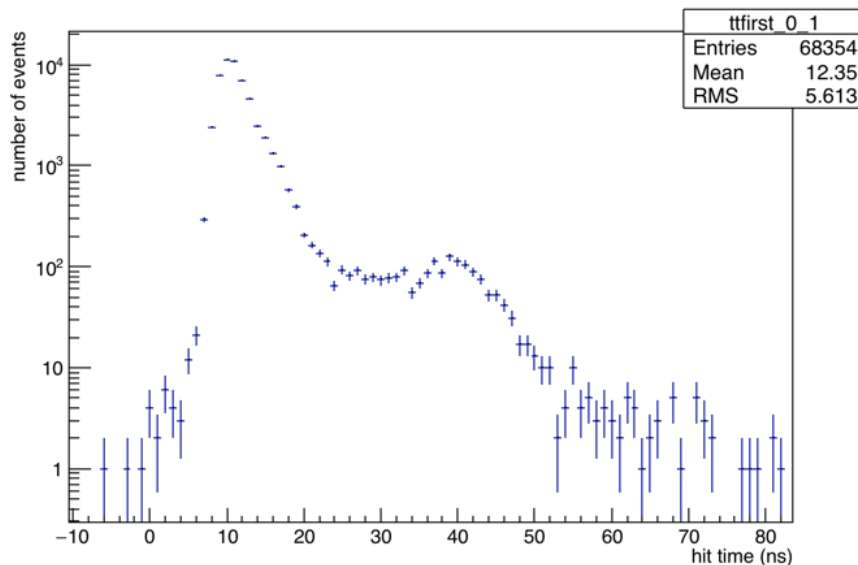
Darkening

- Several hours of rate monitoring.

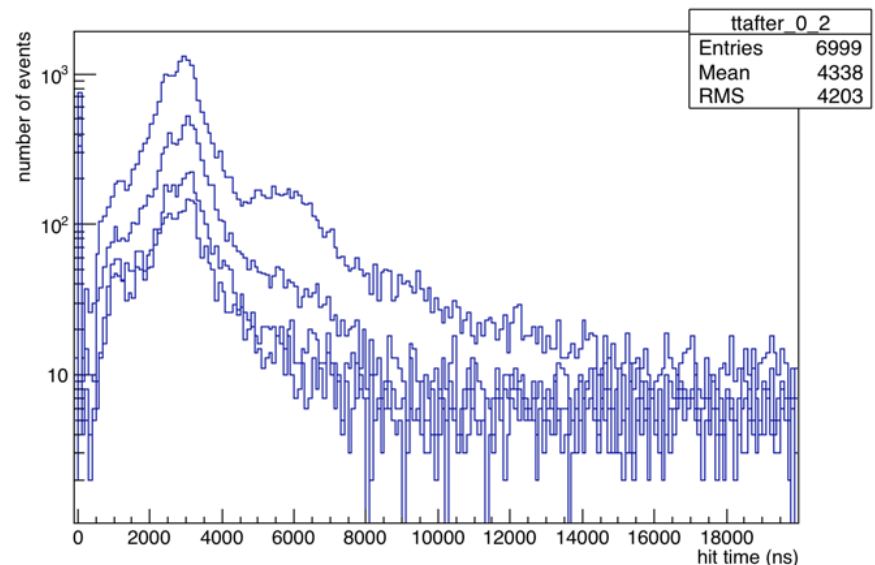


Laser measurements

- First hits are collected to determine TT peak, TTS, prepulses, delayed pulses.
- Secondary hits are collected to determine afterpulses.

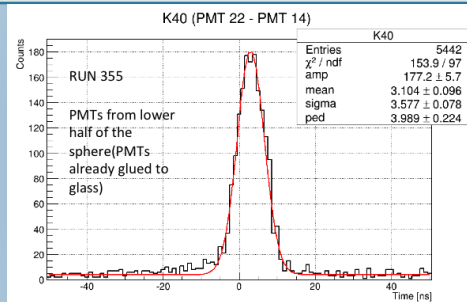


First hits (-10, 100 ns)

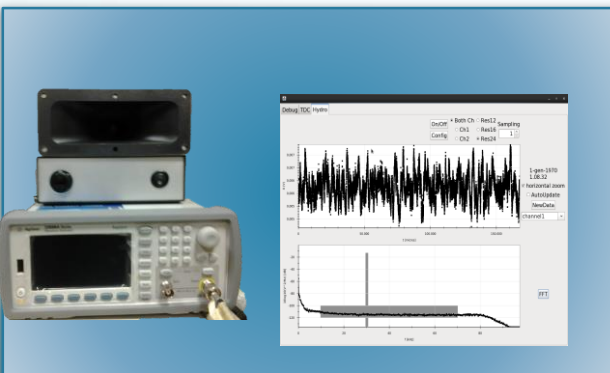


Secondary hits (0 – 20 μ s)

DOM acceptance tests

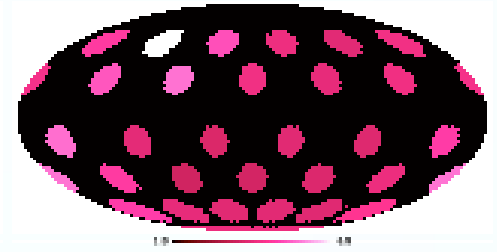
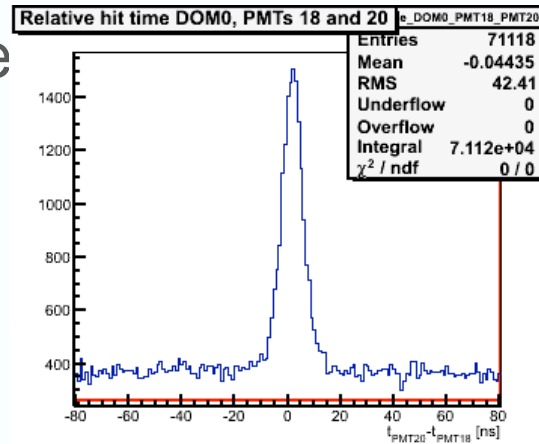


- Temperature, humidity, pressure check.
- PMT tests
 - dark rates test after integration: effects of the structure, glass, gel
 - Time calibration with laser (4 reference PMTs).
 - K40 coincidence rates: PMT placement check + PMT time intercalibration.
- LED beacon test.
- Piezo qualification.
- AHRs calibration: magnetometer scans (3D rotation).
- Electronic test (WR synchronization, DAQ system is equivalent to the final detector DAQ).

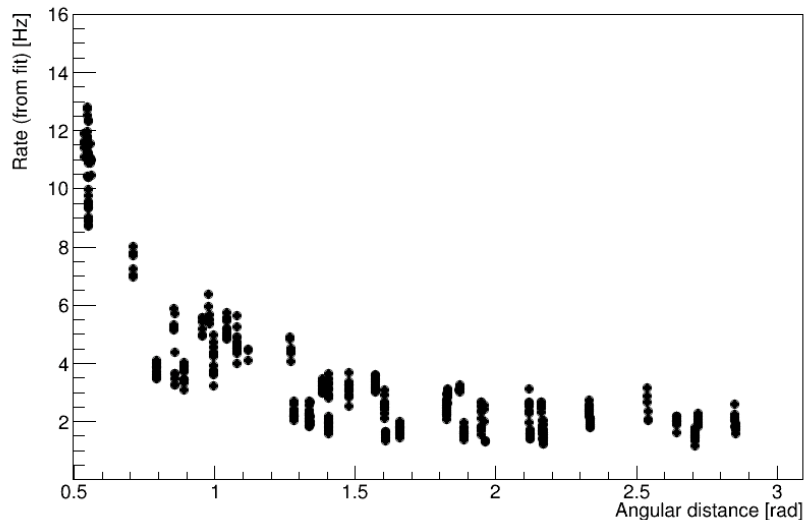


K40 calibration

- K40 decays in glass, ge are seen by the neighbor PMTs. Rate depends on the angular distance.

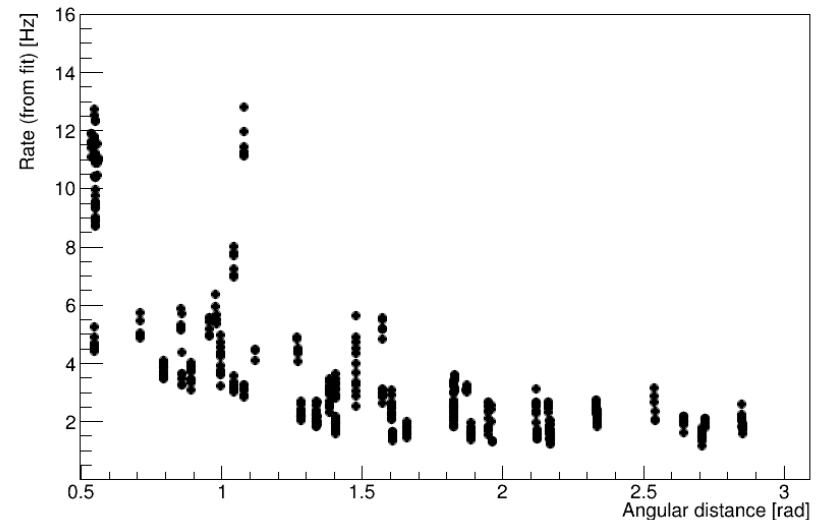


DOM 9



DOM with proper PMT numbering.

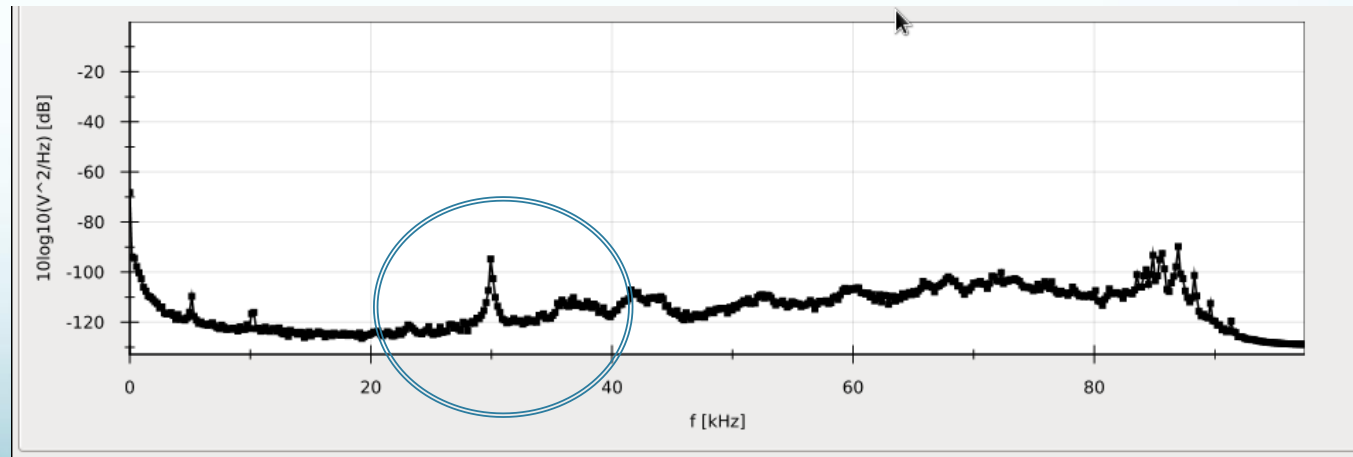
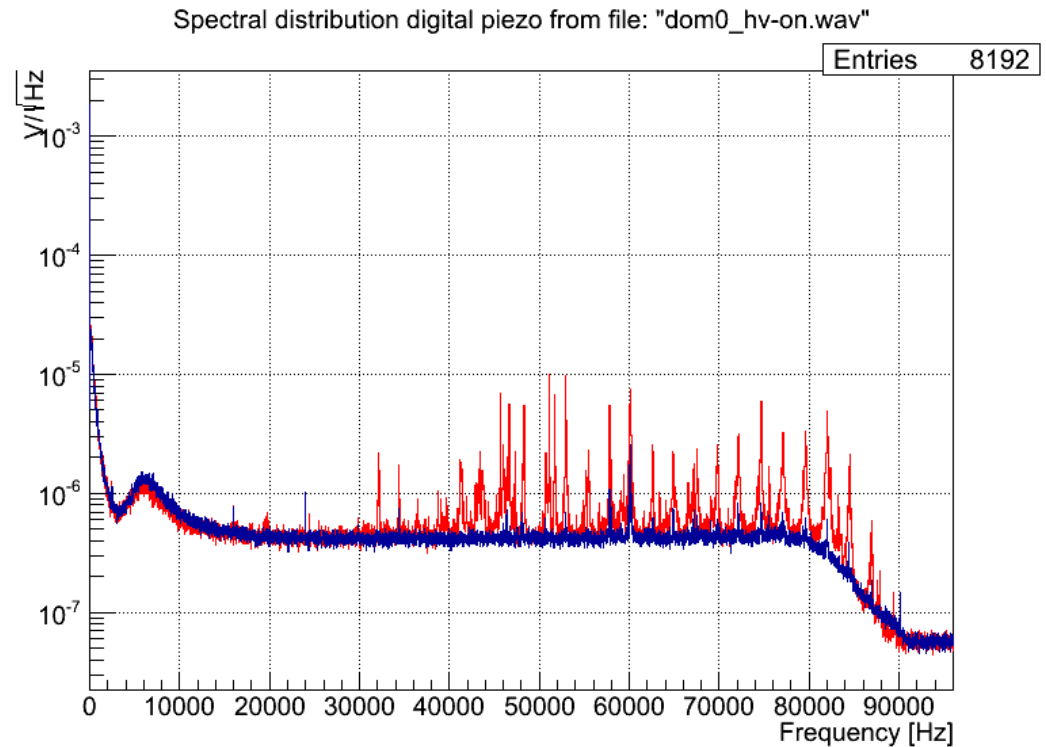
DOM 9



DOM with wrong PMT numbering.

Piezo calibrations GreenBox

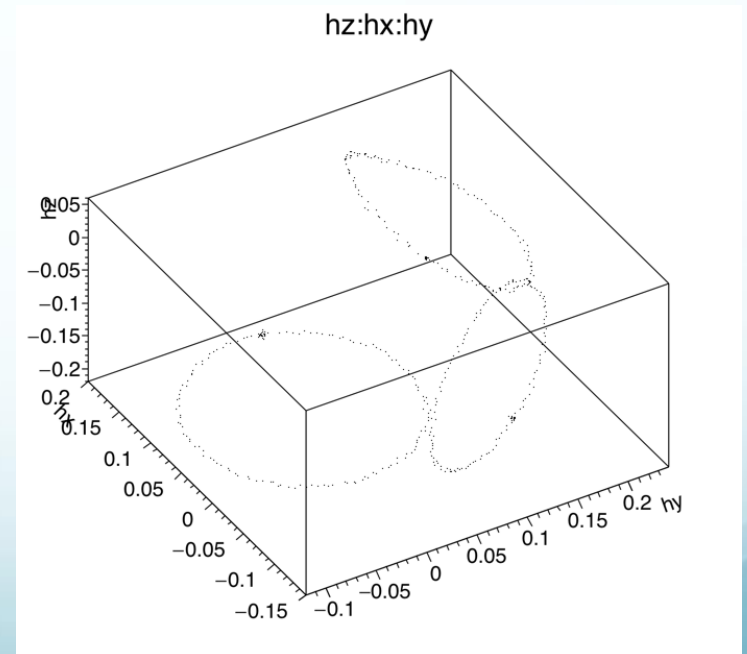
- Noise level (increases when PMTs are ON)
- Test with 30 kHz sound emitter



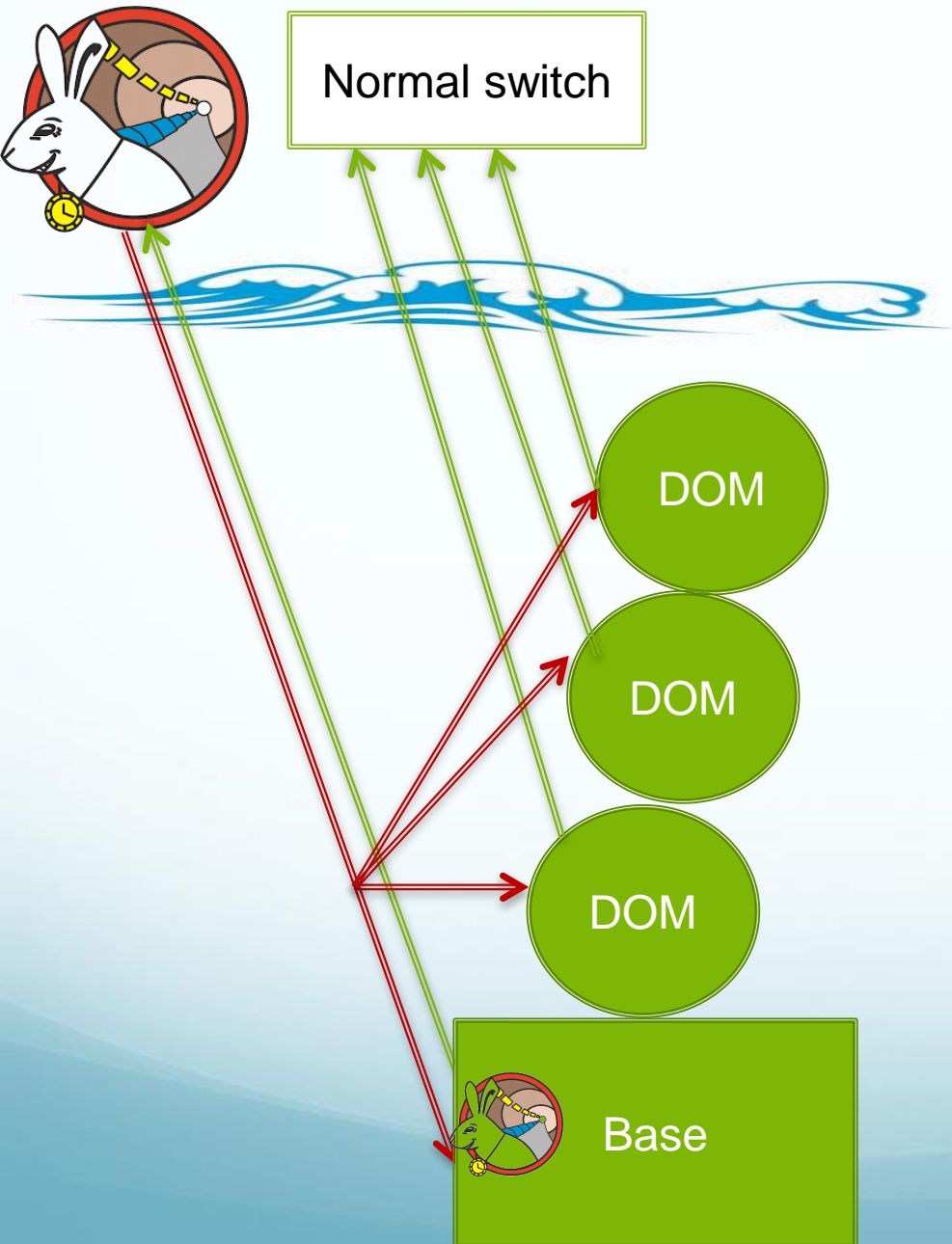
AHRS calibration



- AHRS comprises magnetometers, accelerometers and gyroscopes. Sensor fusion algorithms (Kalman filter) are used for yaw, pitch, roll calculation.
- Magnetometers calibration to compensate for the internal fields (due to metal components).
- Earth field makes sphere when the DOM is rotated.
- Rotation in three planes (XY, YZ, ZX) using automatic rotation table.
- Orientation check for 4 directions (N,E,S,W).



Time synchronization



- The **longest fiber** (~50 km in Toulon, 100 km in Capo Passero) is **common** for the base and the DOMs.
- Bidirectional connection via single fiber for the string **Base**: WR solution! **Common line delay measurement.**
- Time and control (Slow control) broadcast from the master WRS to all **DOMs**, data return to the data switch. Synchronization thanks to the fixed delays (due to the short paths inside the line)

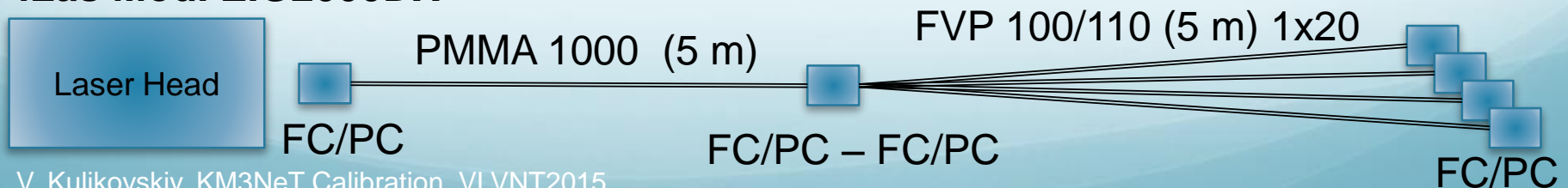
See talk of Gerard Kieft

Time calibrations

- The **longest fiber (~50 km)** is common for the base and the DOMs.
 - One needs to measure delays in not common paths of the base and the DOMs:
 - Base:
 - laboratory calibrations with short 5 m cables (known delay line).
 - Reference CLB with frozen FW (“calibrator”) to monitor delay changes due to CLB FW change/shore station upgrade.
 - Final delay line measurements.
 - DOMs intercalibration: laboratory calibrations with laser in the dark room.
 - PMT intercalibrations: K40.
 - In situ: Laser calibrations, nanobeacons.

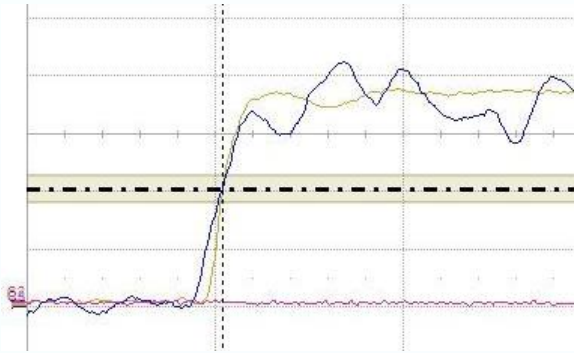


PiLas Mod. EIG2000DX

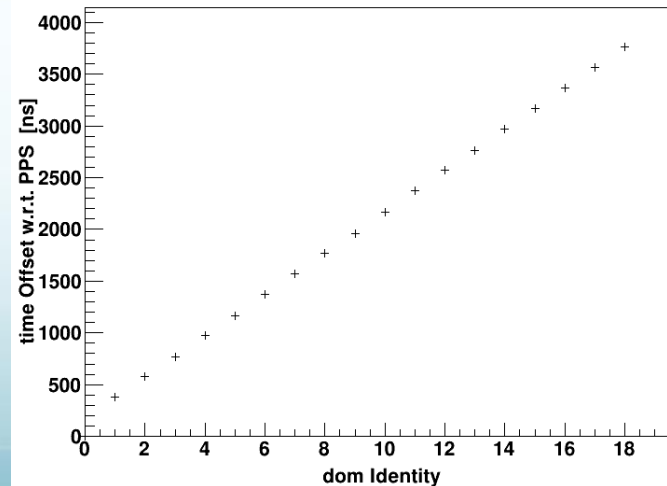
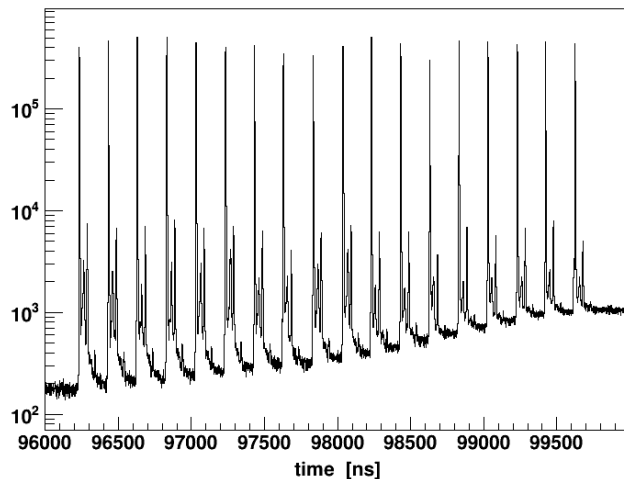


DU-1 calibration

- PPS synchronization (Shore + base) – sub-ns precision.

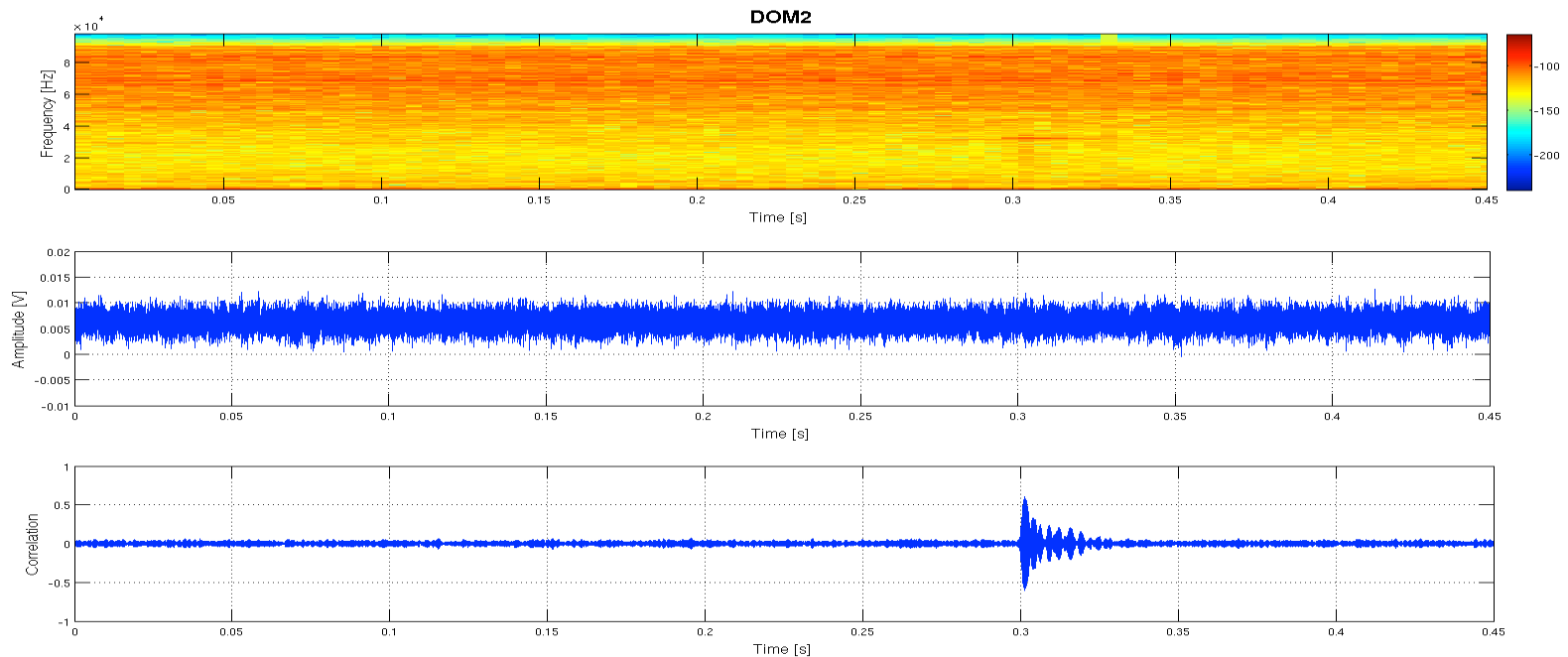


Inter-DOM time calibration with laser

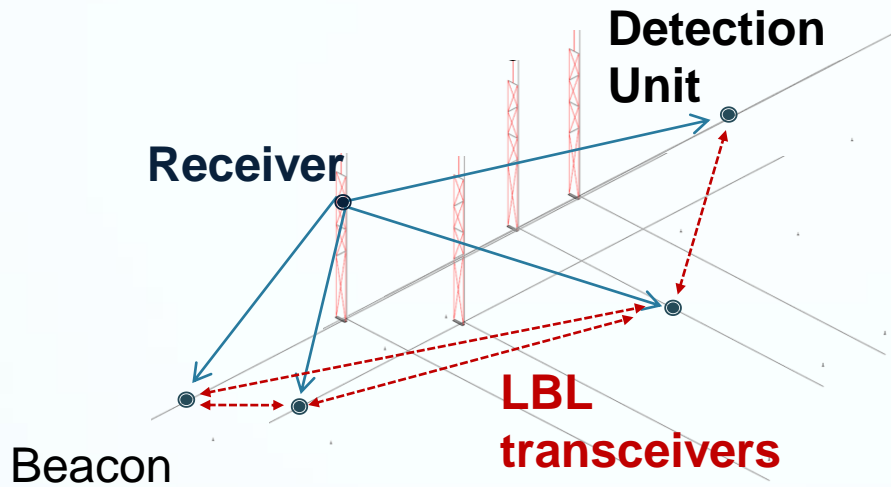


DU-1 calibration: piezos

- Acoustic signal timing (emitter is close to DOM)
- Correlation analysis: emitted signal with a known shape (sinusoidal) vs detected signal + noise.



Positioning



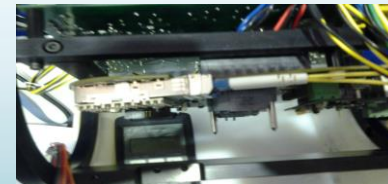
- Acoustic emitters on the calibration lines with known position.
- Hydrophones (sensitive acoustic receivers) in the base of each line
- Piezo receivers inside the DOMs
- AHRS inside each DOM for the orientation



Hydrophone



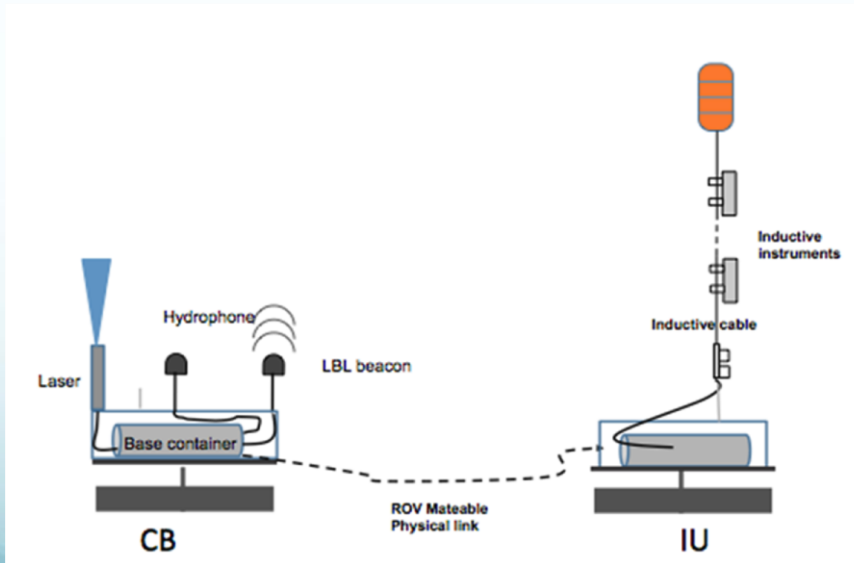
DU Base



See talk of Salvo Viola

Calibration unit

- Calibration Base (CB)
 - laser beacon (interline time calibration + water optical properties monitoring)
 - long-baseline acoustic beacon (positioning for DOMs)
 - Hydrophone (positioning of CB)
- Instrumentation Unit (IU)
 - instrumentation base (electronics interface board and an inductive modem)
 - environmental monitoring instruments (conductivity
 - salinity, temperature, sound velocity, sea currents +?)



See talk of Bruny Baret

Summary

- Calibrations and quality control on different stages in the lab:
 - PMTs – DarkBox at Naples
 - DOMs – Green/Blue boxes at integration sites (NIKHEF, Catania, Naples)
 - Line – first line CPPM (deployment line), next line – integration sites (Naples, NIKHEF)
- Calibrations and monitoring in situ:
 - DOMs:
 - PMTs, Nanobeacons, piezos, AHRS
 - Base line: hydrophones
 - Calibration Units
 - Acoustic receivers/emitters, laser beacons, environmental conditions instruments.