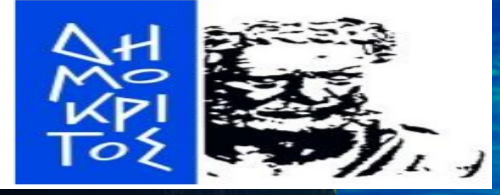

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Measurement of light scattering in deep sea

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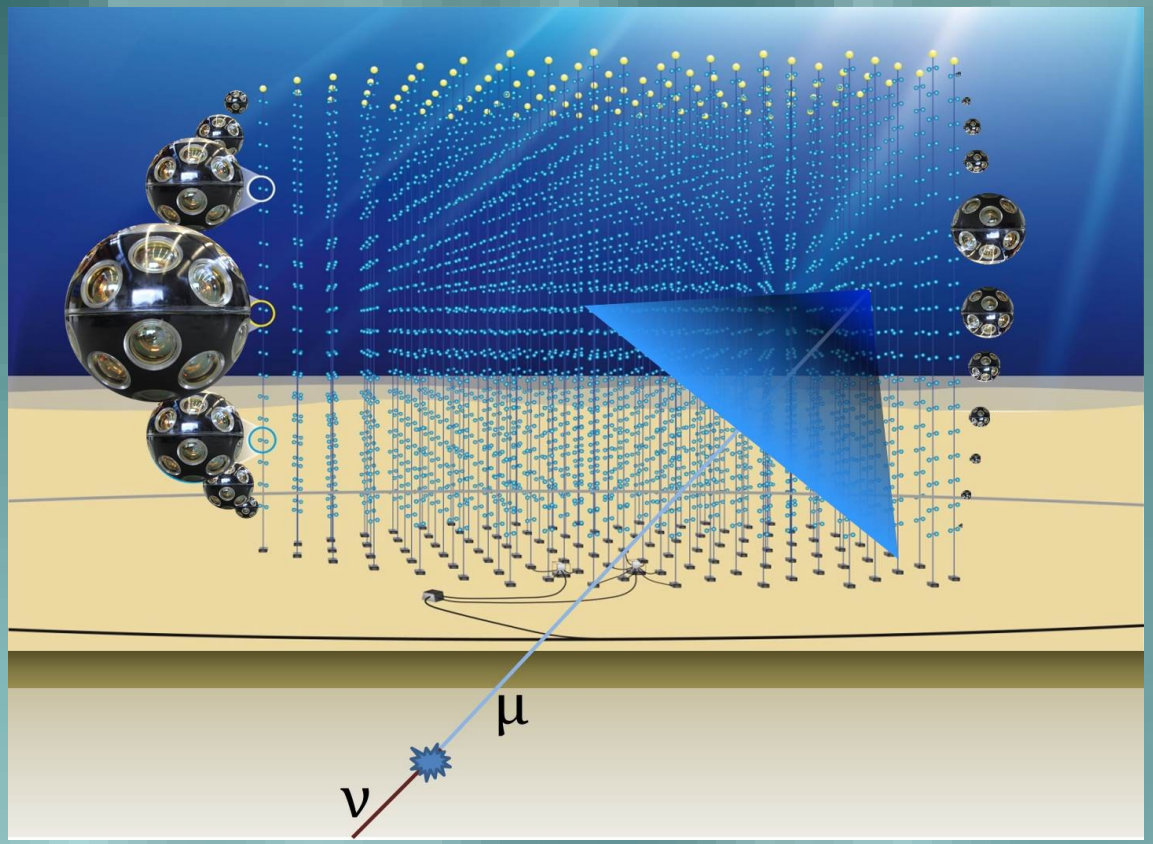
Outline

- **Introduction**
  --Motivation for performing the experiment
  --KM3NeT experiment
- **Scattering model**
- **Experimental set up description**
  --the light source sphere
  --the detector sphere
- **Test of the electronics / laser sources**
- **Deployment - Results**
- **Summary-Conclusions**

Motivation

a observatory for the detection of cosmic point-like neutrino sources

purpose: **detect Cherenkov photons**



Charged-current reactions

$$\nu_l + (A, Z) \longrightarrow (A, Z+1)^* + l^-$$

$$\overline{\nu}_l + (A, Z) \longrightarrow (A, Z-1)^* + l^+$$

Neutral-current reactions

$$\nu + (A, Z) \longrightarrow (A, Z)^* + \nu'$$

$$\overline{\nu} + (A, Z) \longrightarrow (A, Z)^* + \overline{\nu}'$$

optical properties of the sea water of great ineterest for deep underwater detectors

KM3NeT experiment

KM3NeT – DOM: 31 PMTs each 3-inches

Event simulation and reconstruction methods:

- **particles producing the light**
- **PMT functional characteristics**
- ***optical photon processes in the sea water***

Optical processes in the sea water:

- **Absorption**
- **Scattering:** **Rayleigh scattering from sea water molecules**
  Mie scattering from macroscopic particles in sea water

Scattering Model

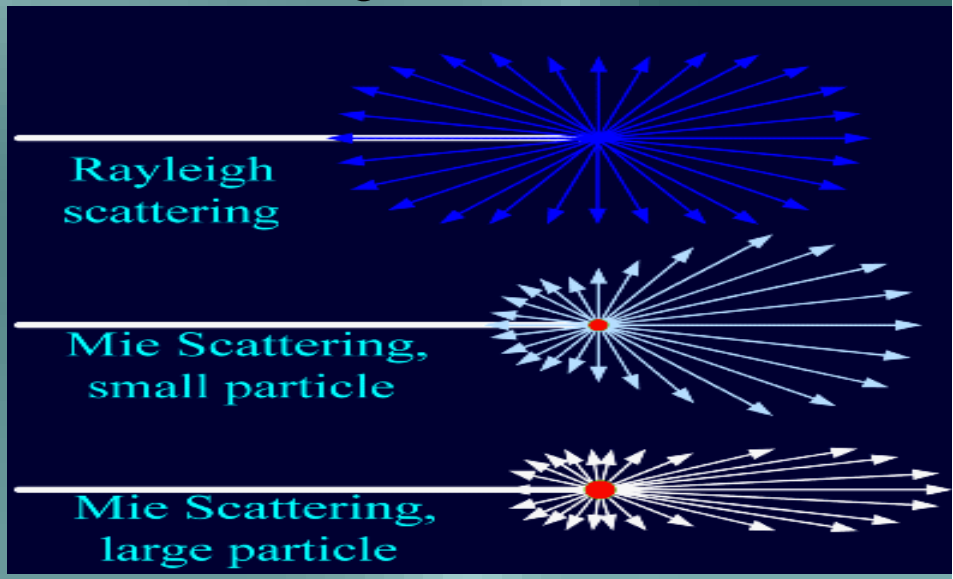
Use combination of Rayleigh and Mie scattering

scattering angle distr.

$$\frac{dP}{d\Omega_s} = F(\cos\theta_s; p, a_{Rayl}, a_{Mie})$$

$$= p \times g(a_{Rayl}, \cos\theta_s) + (1-p) \times f(a_{Mie}, \cos\theta_s)$$

p: Rayleigh contribution
θs: scattering angle



Rayleigh phase function

$$g(a_{Rayl}, \cos\theta_s) = \frac{(1 + a_{Rayl}\cos^2\theta_s)}{4\pi(1 + \frac{1}{3}a_{Rayl})}$$

Mie phase function

$$f(a_{Mie}, \cos\theta_s) = \frac{1}{4\pi} \frac{(1 - a_{Mie}^2)}{(1 + a_{Mie}^2 - 2a_{Mie}\cos\theta_s)^{\frac{3}{2}}}$$

$$\langle \cos\theta_s \rangle = a_{Mie}$$

Site Selection

---Close to the coast

--- depth of 4500 m

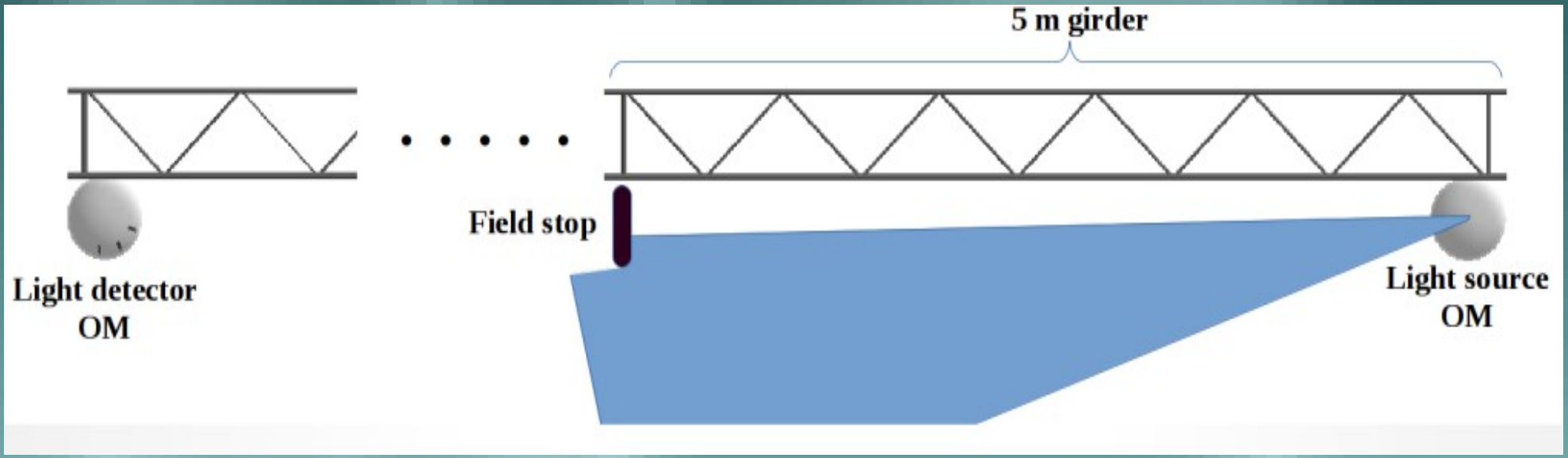
---Good optical properties in water

---Low level of bioluminescence

---Low rate of sedimentation

---Low velocity bottom current

Experimental set up



- Each OM will be attached in is own **5 m long metal girder**

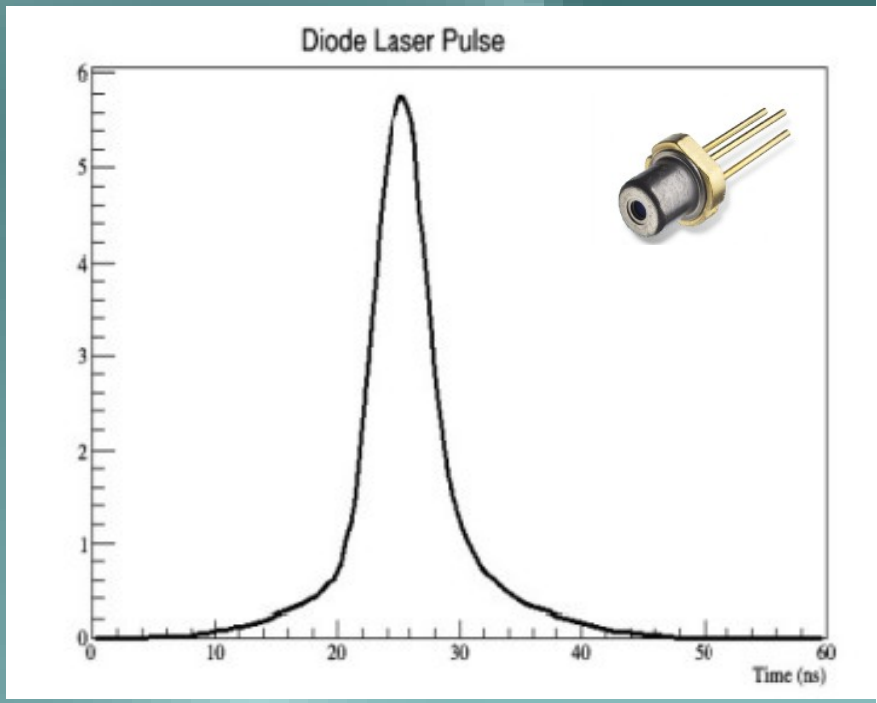
- The experimental setup will be deployed tree times inside the deep sea water, each time with different distance between the OMs. (**10, 15, 20 m** respectively)

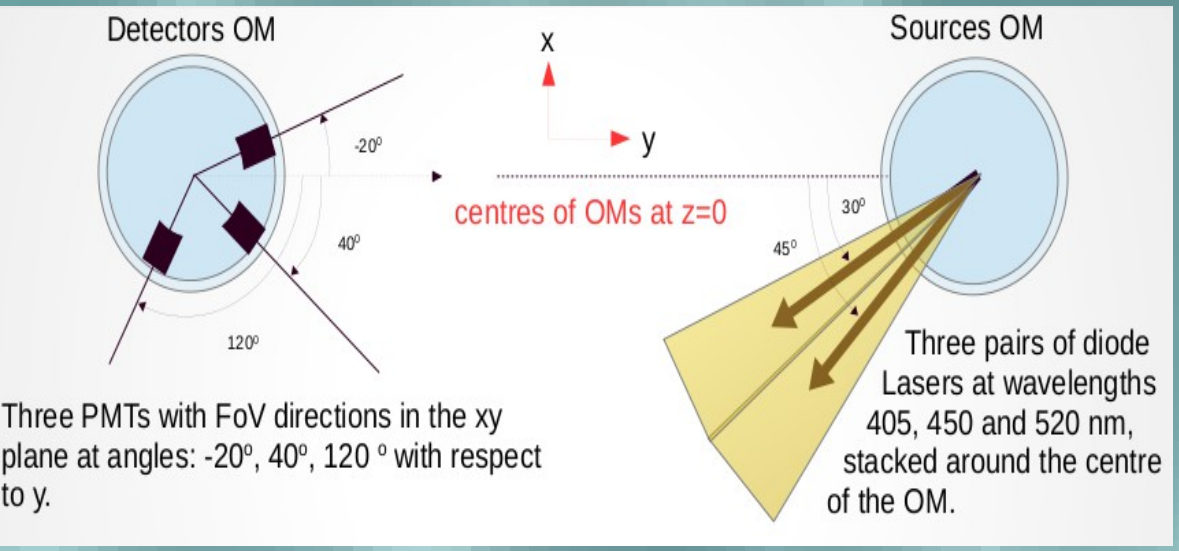
- A **metal disk** attached at the other end of the Light Sources OM girder will be used as a field stop, to prevent blinding of the detectors from direct (un-scattered) light.

Light Source

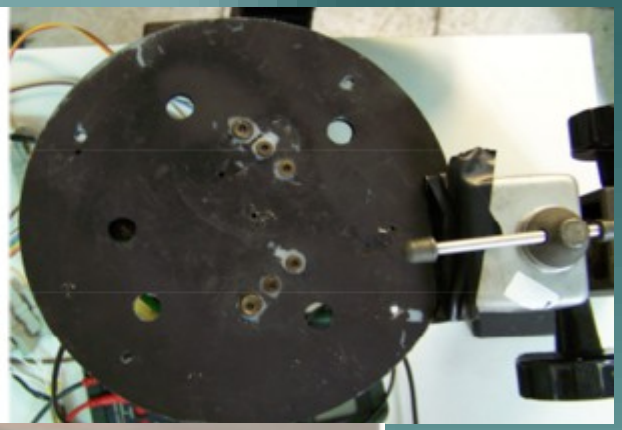
- Diode lasers at 405,450,520 nm
- Pulse width ~ 10 ns
- Pulse energy ~ 2 pJ
- Repetition rate ~ 1 MHz

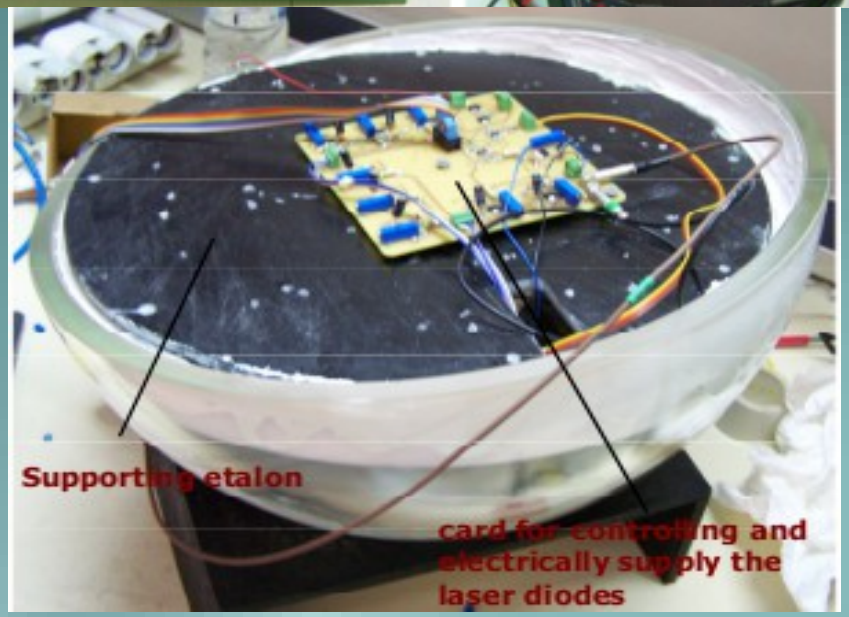
The pulse time distribution of the 450 nm diode laser as measured with an APD





Apparatus

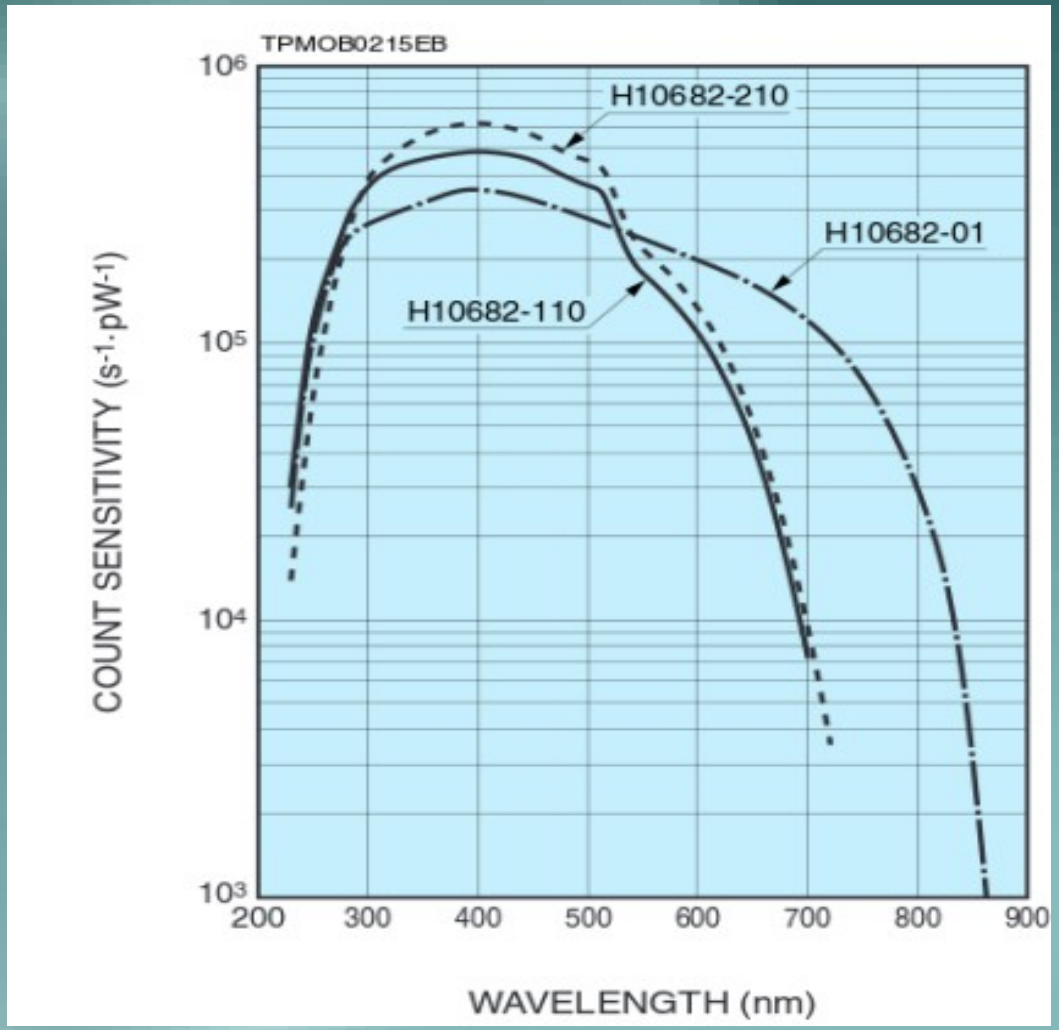



Supporting etalon
card for controlling and electrically supply the laser diodes

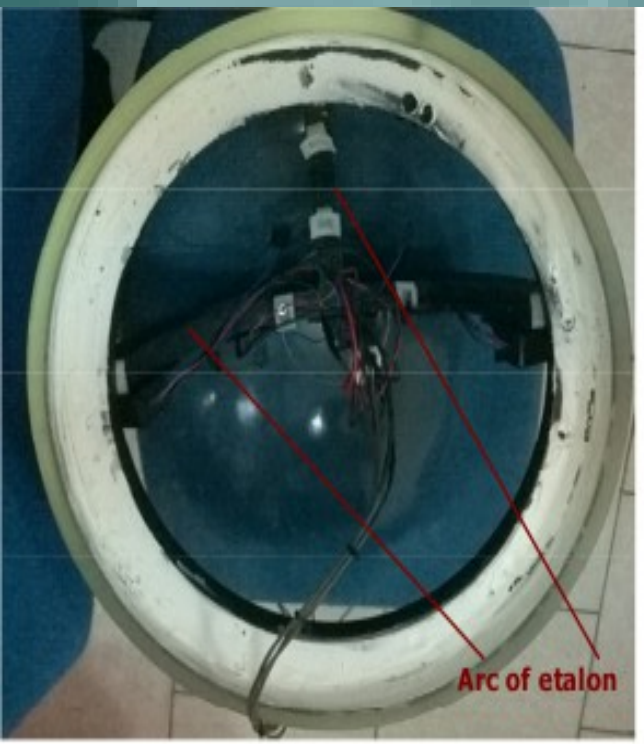
Detector

HAMAMATSU H10682-210 PMT
ultra bialkali

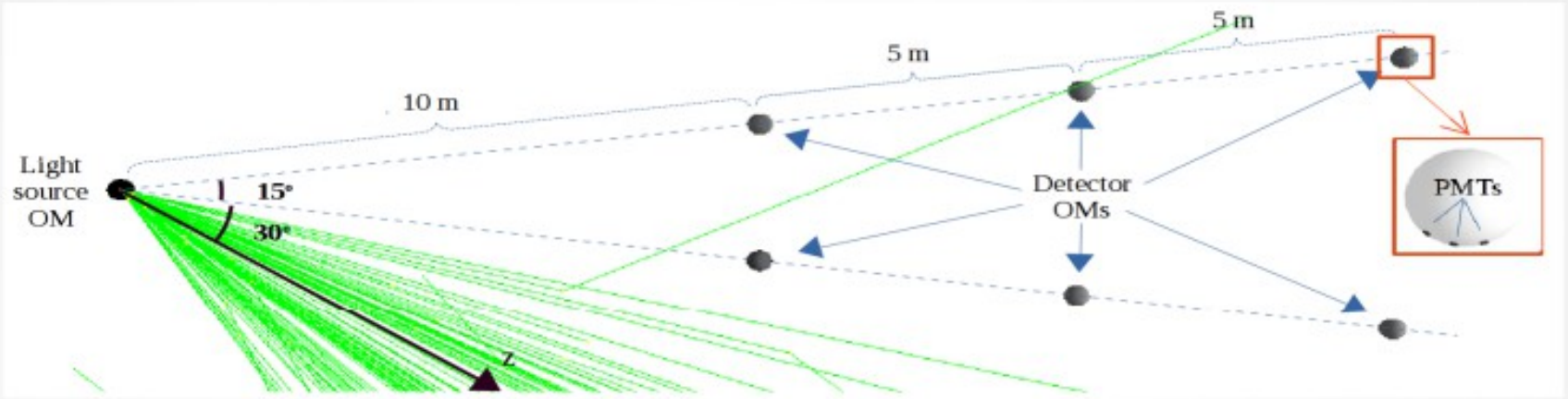
- QE=30%
- Pulse-pair resolution: 20 ns
- Effective area: ϕ8 mm
- Dark Count: 50 Hz



Apparatus



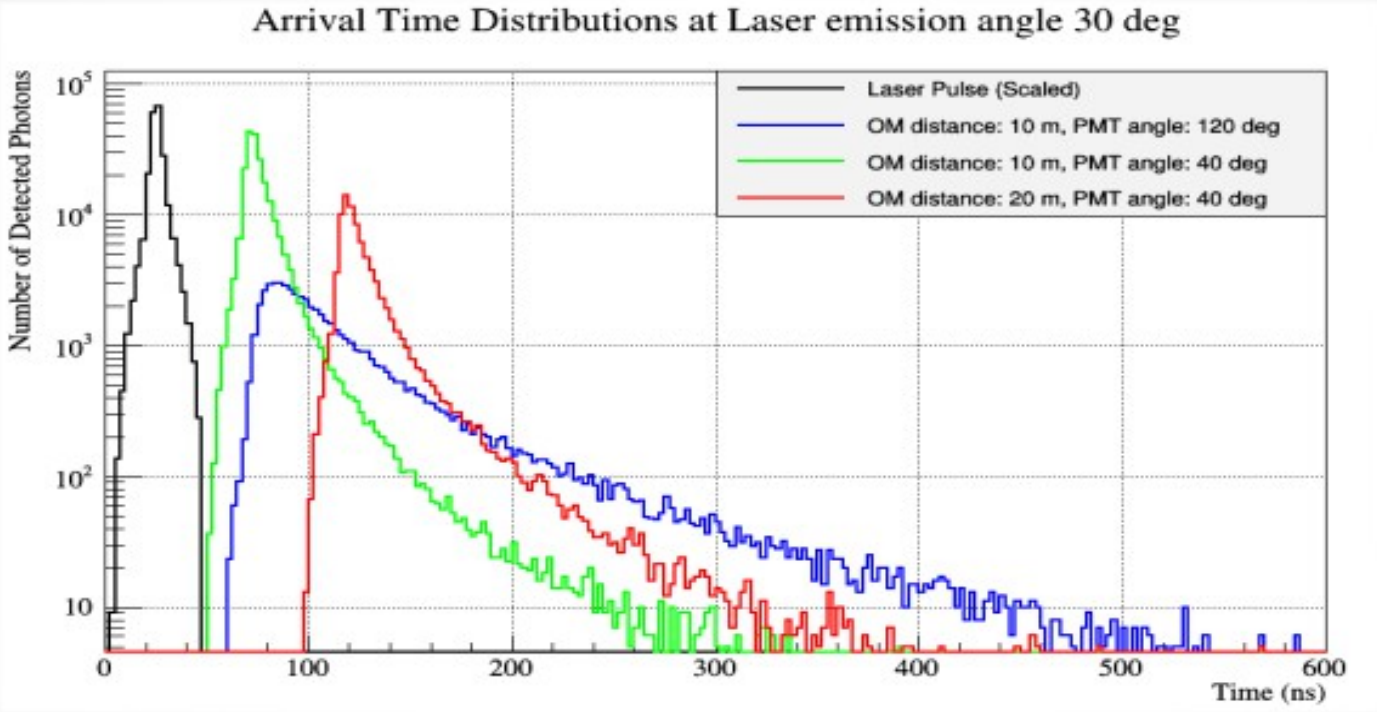
Simulation



- Simulation Parameters to be estimated from the experimental data
  - absorption length (L_a)
  - scattering length (L_s)
  - Rayleigh contribution (p)
  - Average Mie angle cosine (a_{Mie})

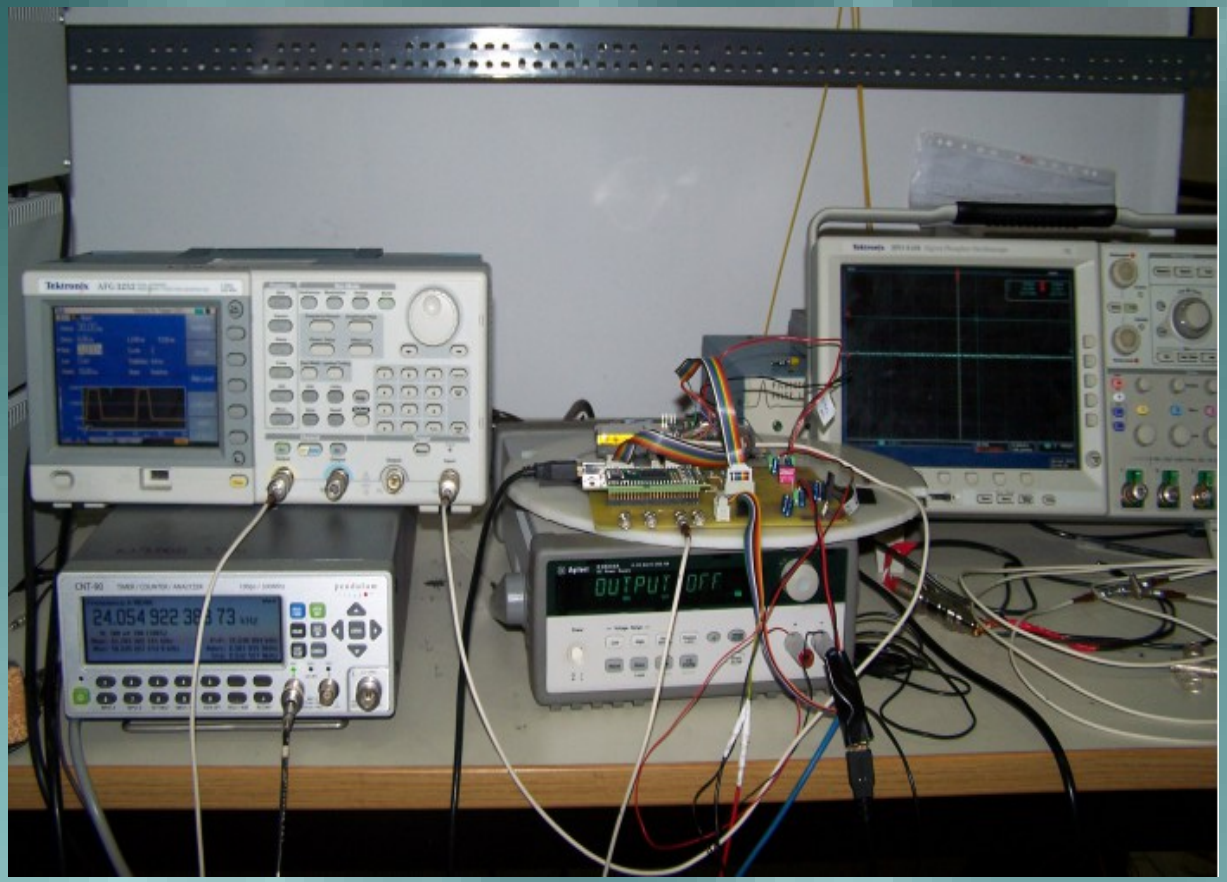
- 10^{12} photon events generated (time and angle distributions according to the laser specifications)
- OUTPUT: detected photon scattering positions, time of flights.
- Event by event scattering angles and arrival times are calculated from output. 18 arrival time distributions are derived.

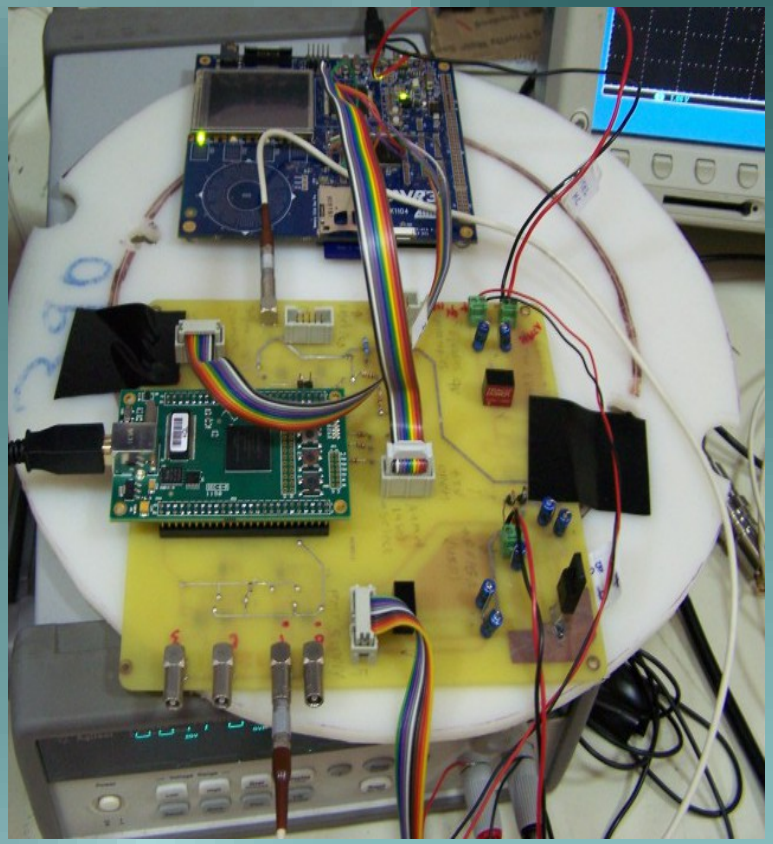
Results



OM distance (m)	10	10	20
OM angle (deg)	30	30	30
PMT angle (deg)	120	40	40

Test of the FPGA/electronics system





General set up that was used for performing our tests at the Dumand Lab in Pylos

Delay of underwater connection cable under pressure

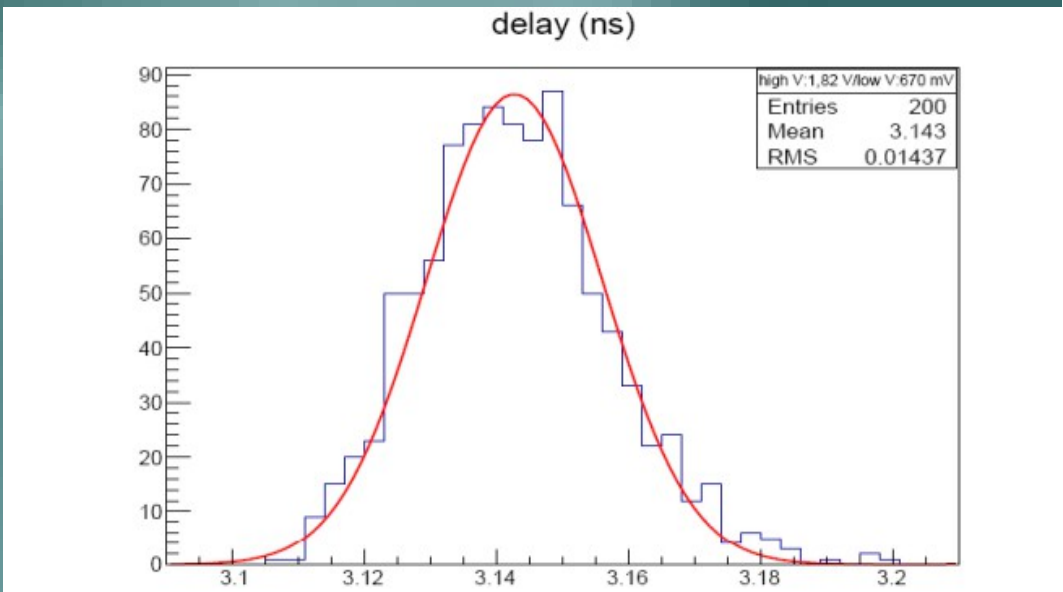


Figure I2 The delay (in ns) of the signal, as measured at pressure 400 bar, fitted to a Gaussian function.

pressure (bar)	delay (ns)
50	293
100	301
150	305
200	308
250	308
300	310
350	315
400	314

Table 1 Time delay, as the signal passing through the underwater cable at different pressure conditions.

Voltage drop under pressure

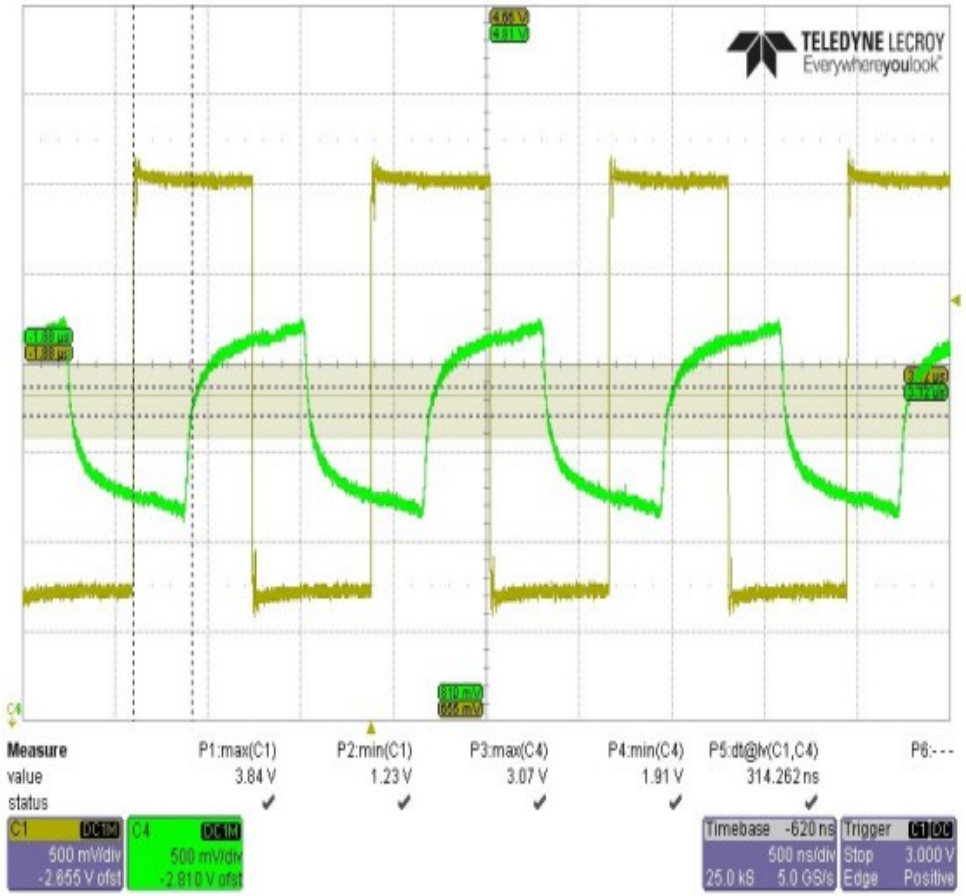


Figure I1 Original signal of 3,84 V that fed the oscilloscope directly (yellow colour) and the signal the came out from the underwater cable (green colour) at 400 bar.

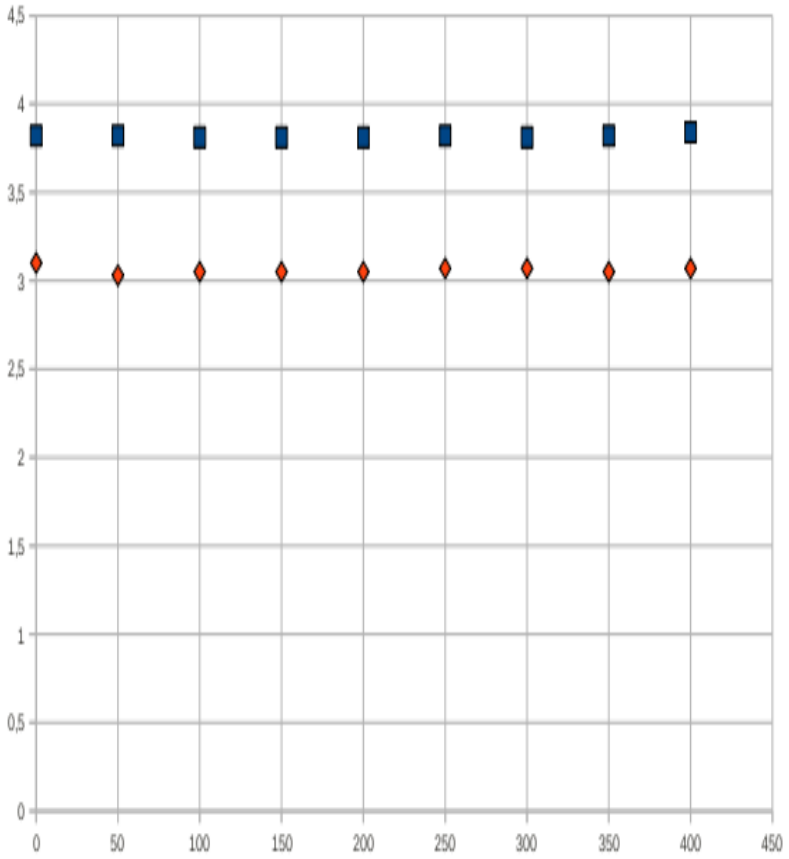
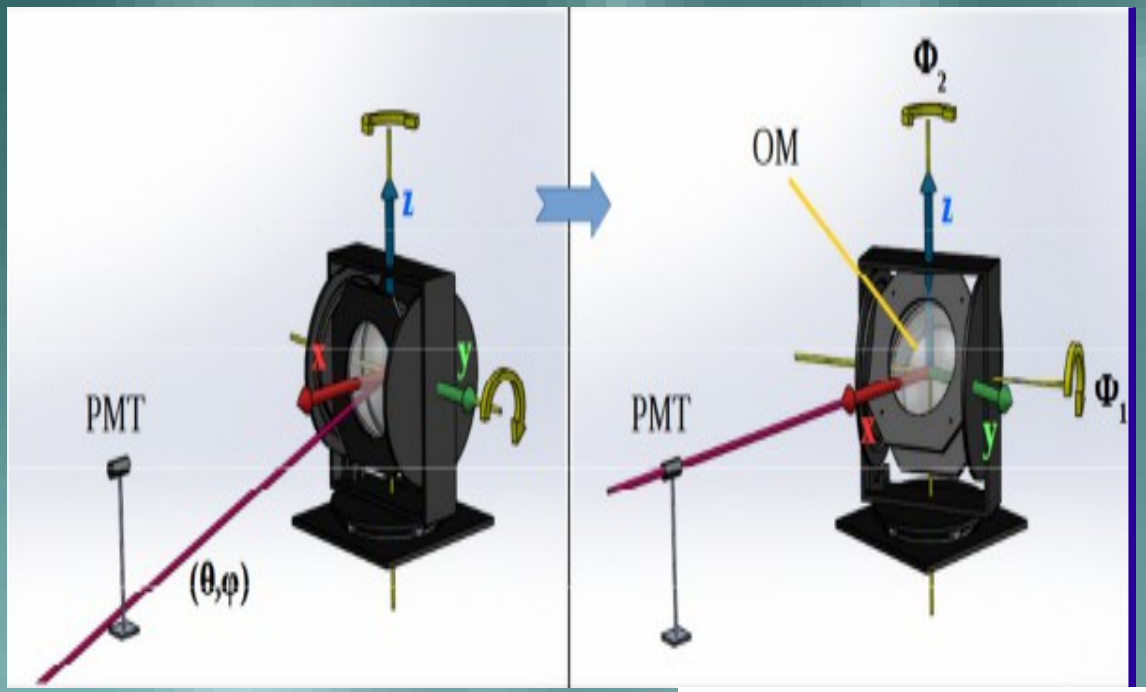
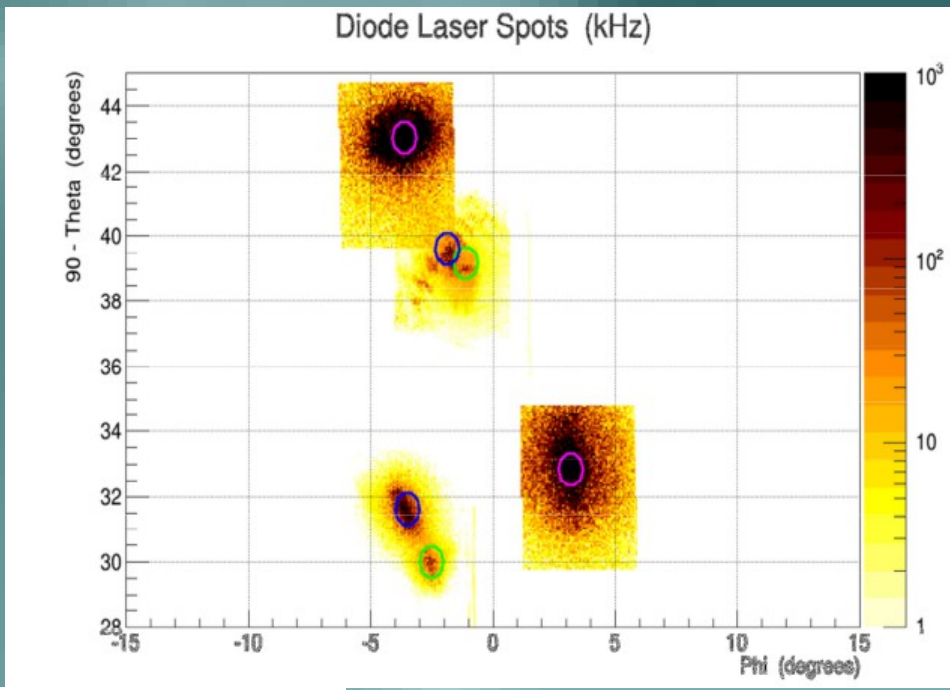
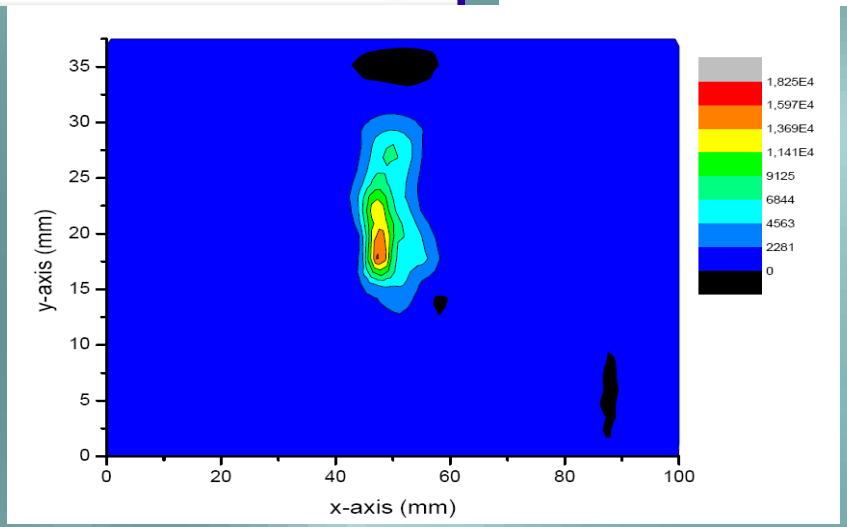


Figure 2 Maximum voltage of the input (blue colour) and output (red colour) signal for each pressure value under test.

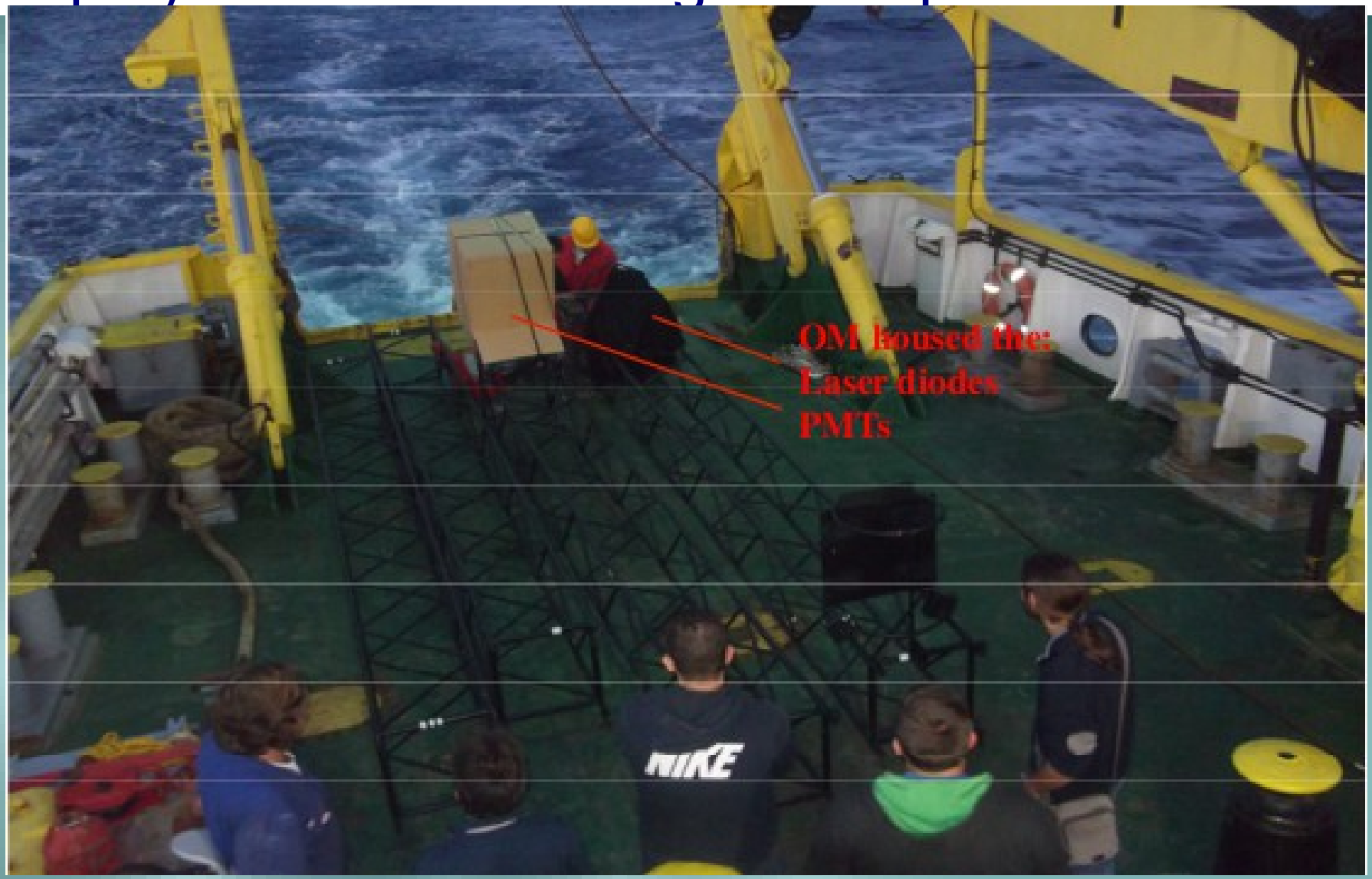
Scanning the laser sources



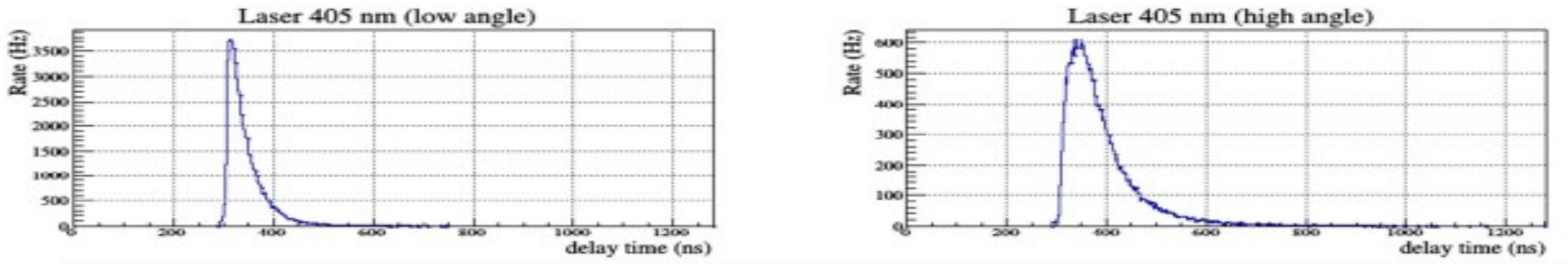




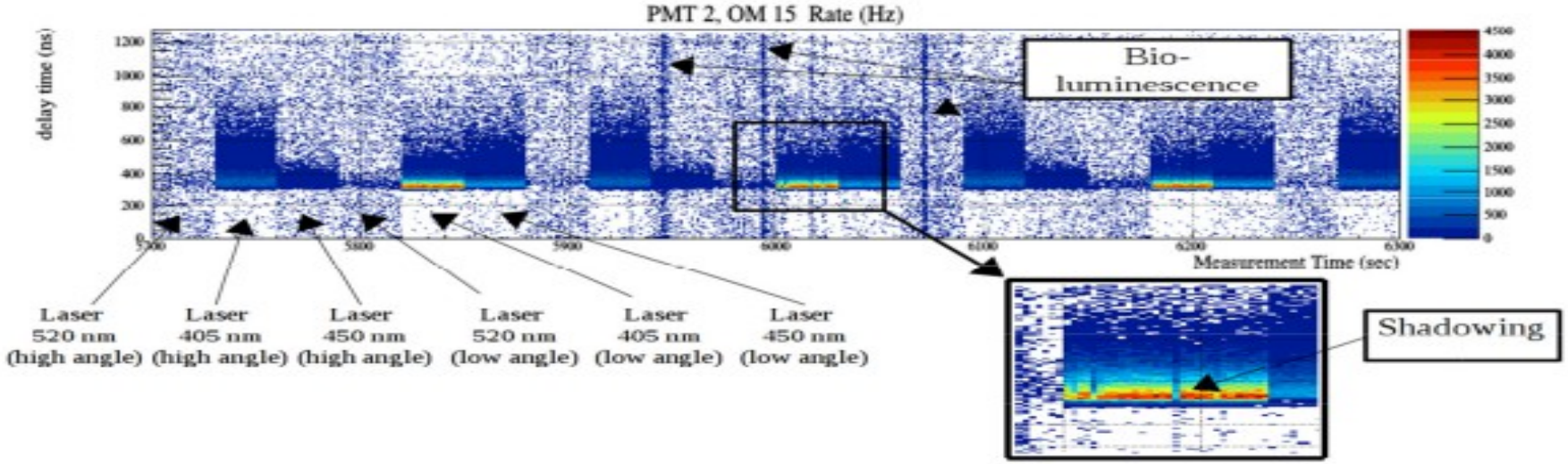
Deployment with the Aegeon ship of the HCMR



Deployment with the Aegeon ship of the HCMR



ıre 2 *Photon arrival time distributions as detected from a PMT in the second deployment (~15 m OMs distances)*



ıre 3 *Part (600 sec) of the "measurement history" as recorded from PMT 2 at the second deployment. In x is the real time of the measurement in seconds; in y are the time channels in the 1280 ns "time window" and in z the hit rate in Hz for each measurement second at each time channel. The 30 sec operation cycles of each laser as well as bioluminescence and shadowing due to life activity can be observed.*

Conclusion

1)study the design of an experimental set up for in situ measurement of the scattering parameters in deep sea

2)deployed with success

3)processing data

4)almost ready for publication

Thank you for your attention

Pylos, 2016

KONSTANTIA BALASI