Light pollution due to artificial light sources

ATRIUM-369370

KM3NeT_IS FR_2019_022

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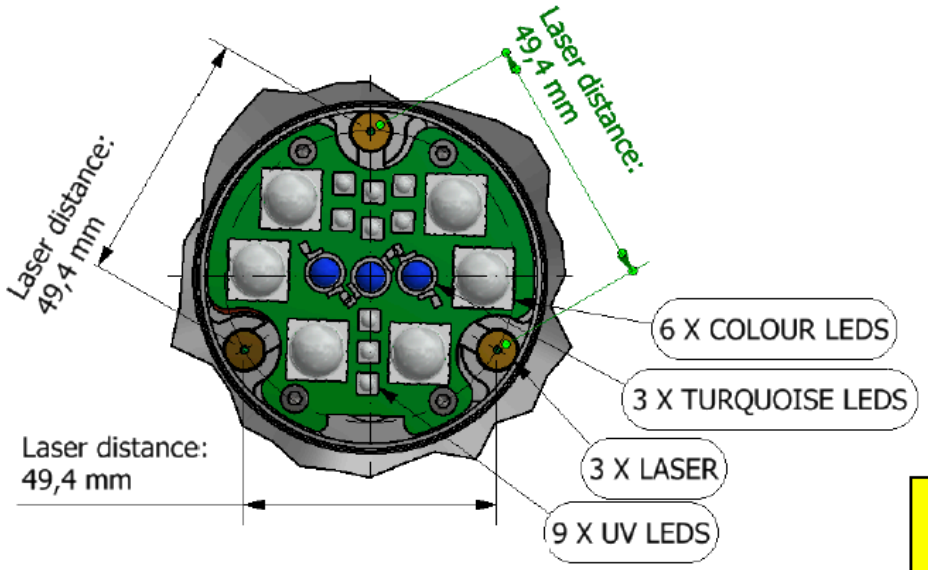
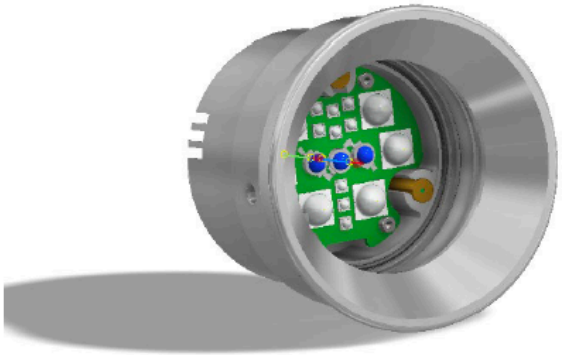
Crawler Wally

- Layout of the light module





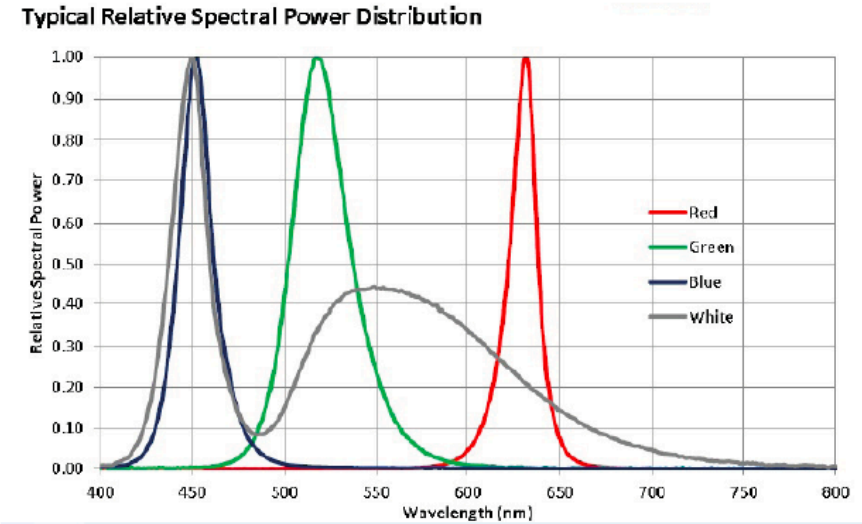
Warning.

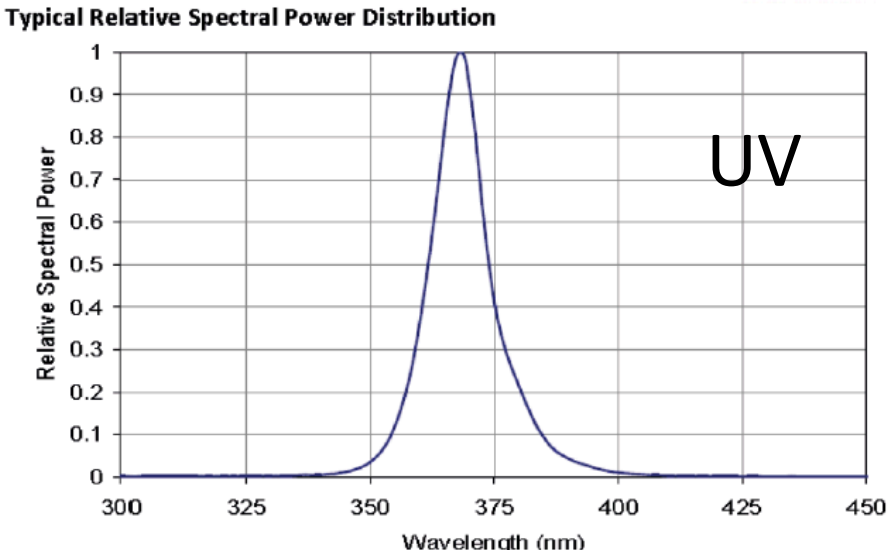
Never look into the light when on

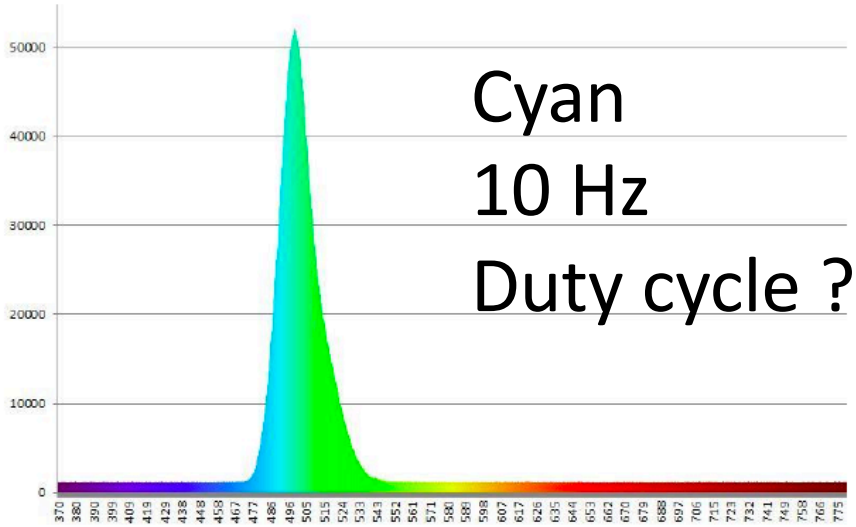
The intensity of the LEDs and the laser light can give serious damage to your eyes!

Crawler Wally

- Frequencies, characteristics







Laser λ = 532nm
LED also narrow band

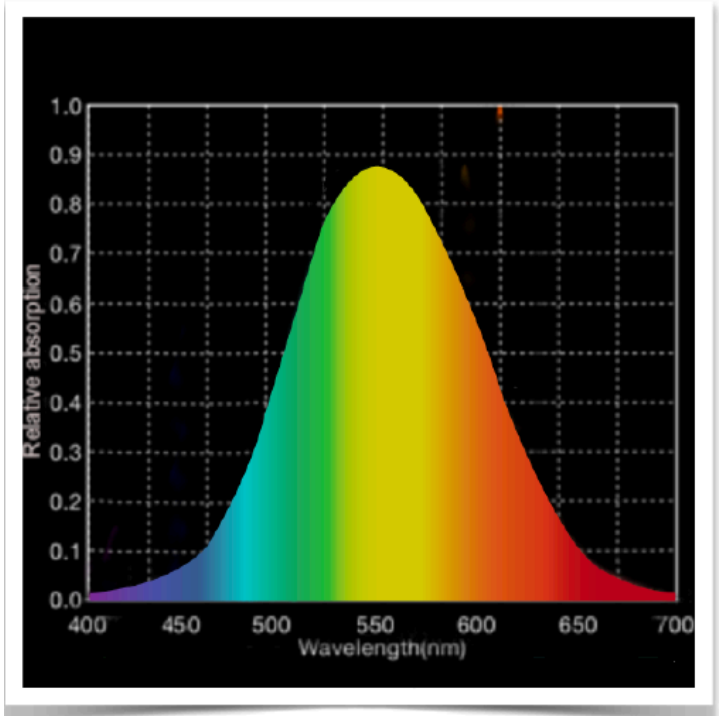
Summary of planned light sources

- Several unknowns
  - Reflections
  - Angular profile
  - Pulsing profiles
- Simulate individual wave lengths

Device	Color	Wavelength	power	Flux
Biocam	Red	625 nm	no data	30.6 lm
Biocam	Green	527 nm	no data	67.2 lm
Biocam	Blue	457 nm	no data	8.2 lm
Biocam	White	6300 K	no data	100 lm
Crawler	Red	630 nm	53 W	4800 lm
Crawler	Green	532 nm	3x5 mW	laser
Crawler	Green	520 nm	60 W	5400 lm
Crawler	Cyan	490 nm	9 W	10 Hz
Crawler	Blue	450 nm	12 W	1150 lm
Crawler	UV	365 nm	9 W	—
Crawler	White	— nm	111 W	10000 lm

Lumen versus photons

- Conversion needed
- 1 lumen = 4.11 10^{15} photons at λ = 555 nm
- Fold in sensitivity of human eye

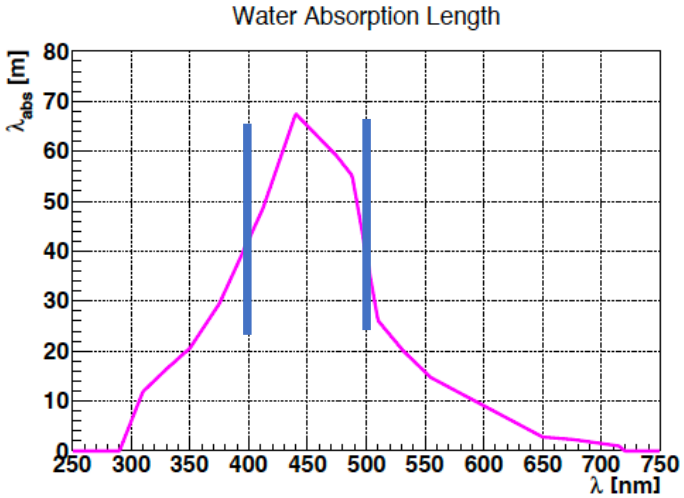


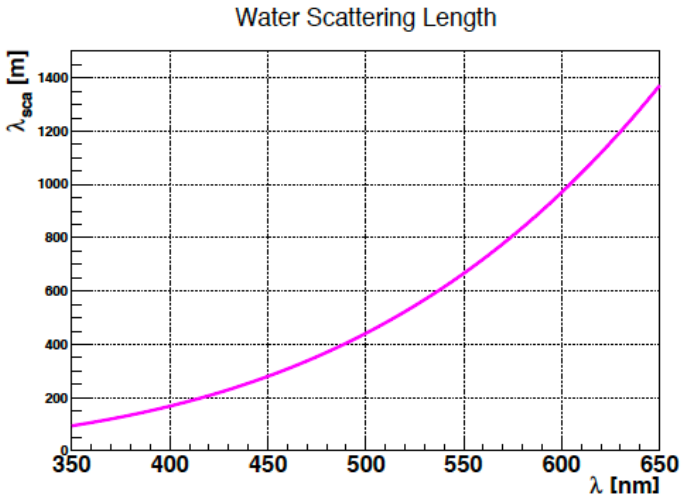
wavelength	< 450 nm	450 nm	500 nm	550 nm	600 nm	650 nm
C_l	20	20	2	1	2	20

Water parameters

- Absorption & scattering with wavelength dependency
- Particle scattering ignored

$$L_{sca}(\lambda) = \left\{ \frac{\lambda}{550\ \text{nm}} \right\}^{4.32} 667\ \text{m}$$



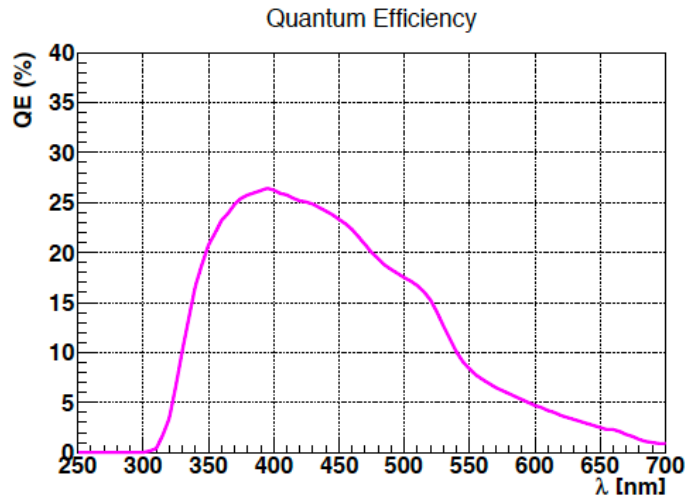


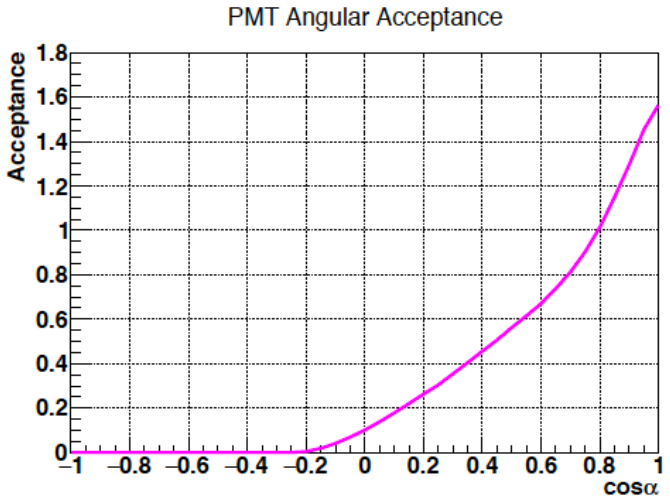
$$\frac{dp_{sca}}{d\Omega}(\beta) = \frac{1}{4\pi} \frac{3}{3+b} (1 + b\cos^2\beta)$$

(b = 0.835)

PMT parameters

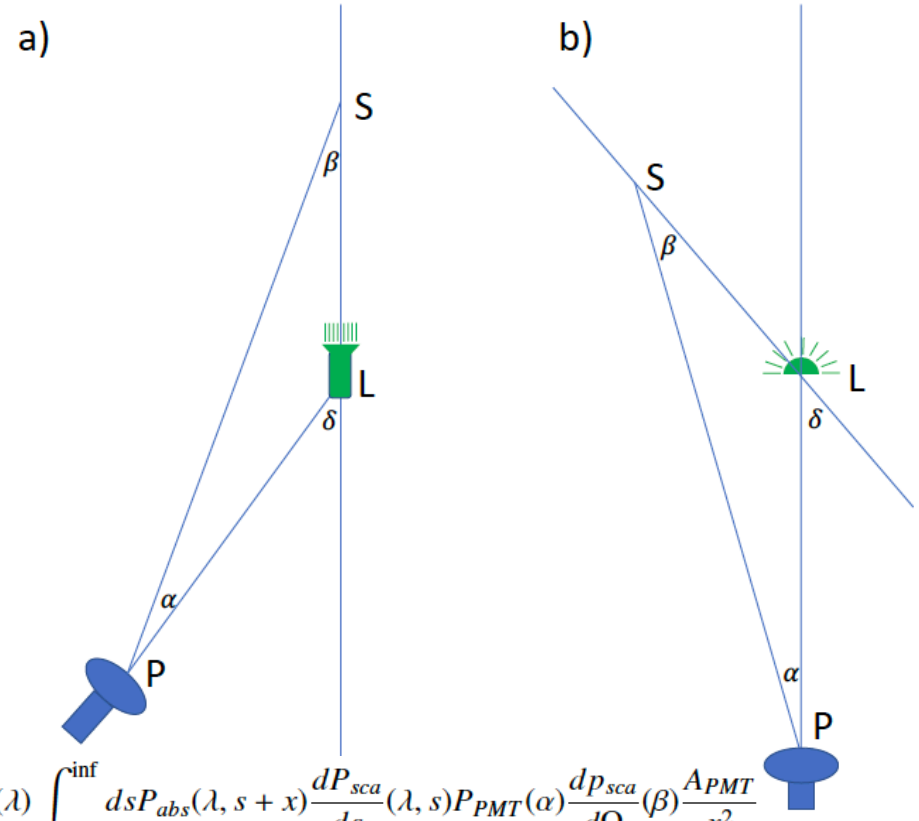
- Quantum efficiency including glass & gel
- Angular acceptance
- From official KM3NeT simulations

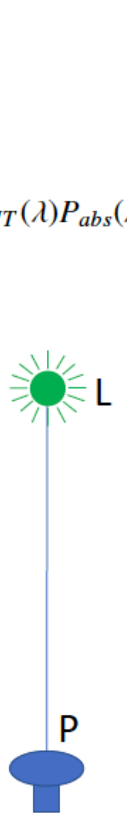




Setups

- Different setups to evaluate uncertainty
- Single scattering approximation
- Low – low – high light yield



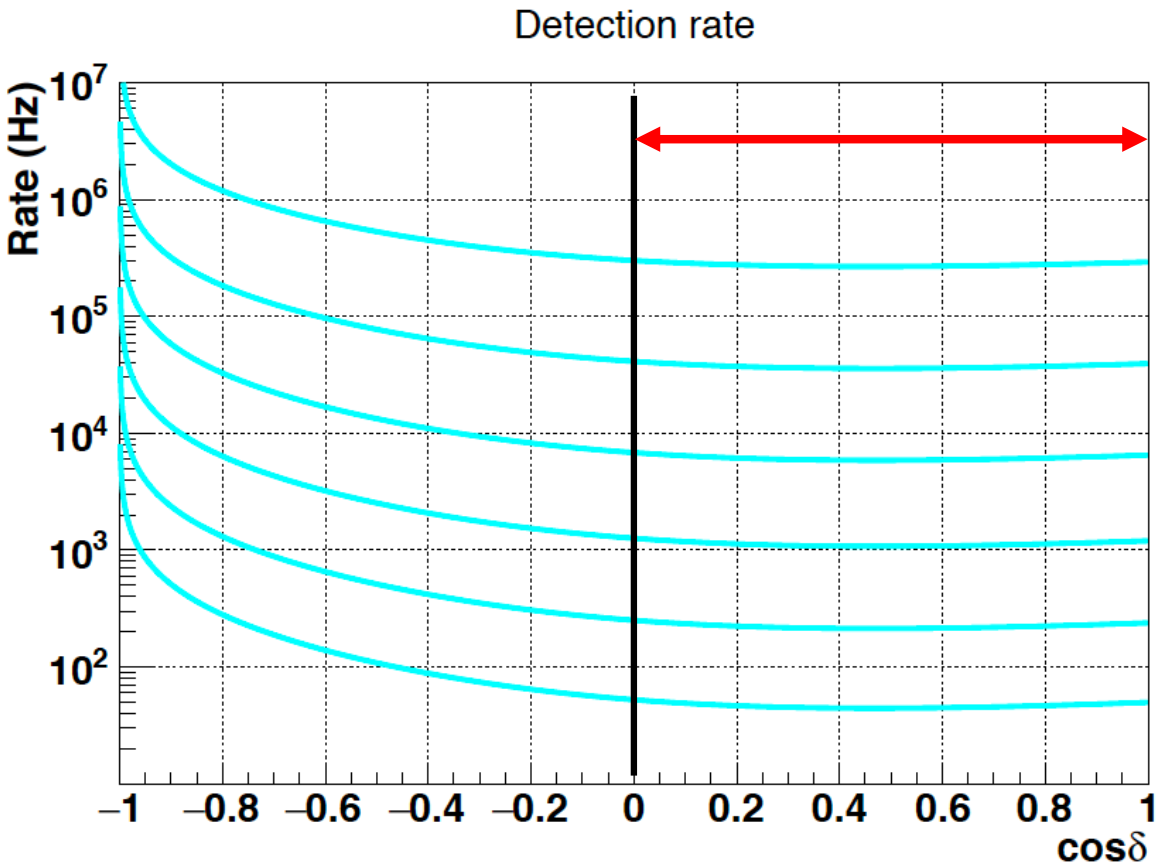


$$R(\lambda, d) = \Phi_0(\lambda) QE_{PMT}(\lambda) P_{abs}(\lambda, d) P_{PMT}(0) \frac{A_{PMT}}{4\pi d^2}$$

$$R(\lambda, d, \delta) = \Phi_0(\lambda) QE_{PMT}(\lambda) \int_0^{inf} ds P_{abs}(\lambda, s + x) \frac{dP_{sca}}{ds}(\lambda, s) P_{PMT}(\alpha) \frac{dp_{sca}}{d\Omega}(\beta) \frac{A_{PMT}}{x^2}$$

Results

- Setup a) angular distribution
- Rather flat in back hemisphere → use b)

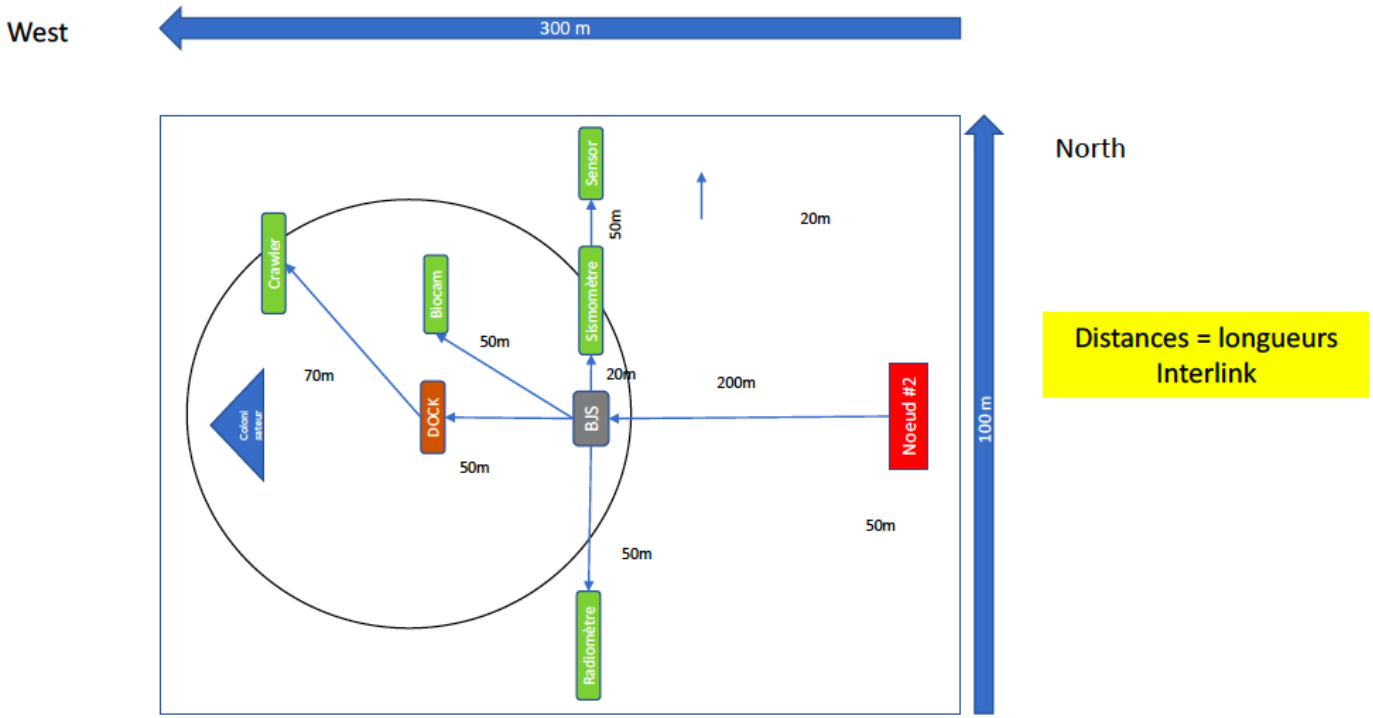


λ = 500 nm (1 lumen)

d = 100m
d = 150m
d = 200m
d = 250m
d = 300m
d = 350m

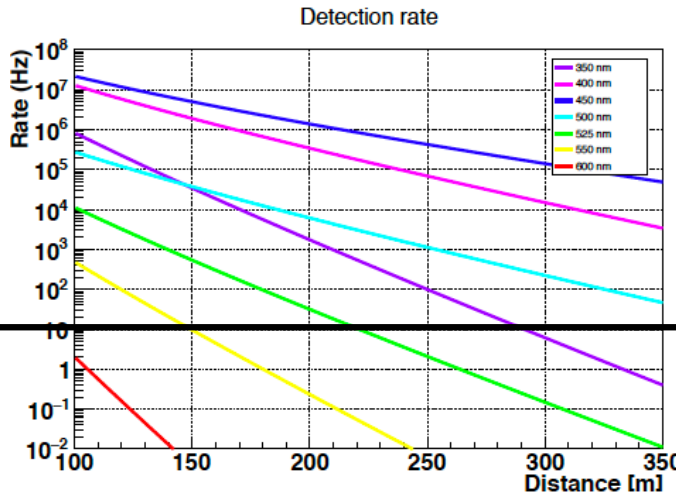
Setup on sea floor

- From design, focus on 200m – 250m

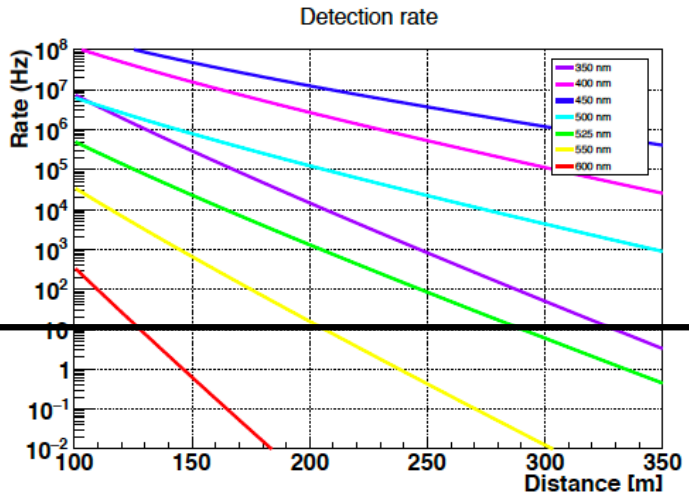


Results

- Reference source 1 lumen
- Background light from ^{40}K 6-7kHz
- Acceptable additional background 1 kHz
- Setup b) (low)



Setup c) (high)

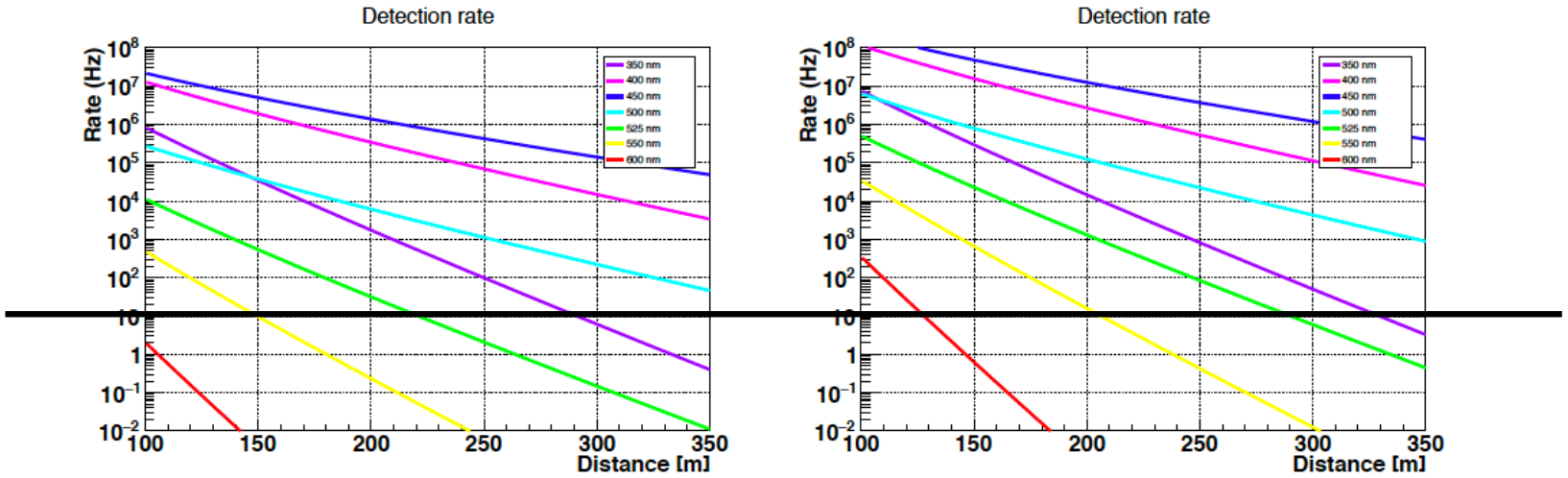


- Limits for 100 lumen == 10 Hz

Results

100 lumen sources with $\lambda < 550$nm cannot be operated at 200m-250m

Wavelength	Distance
350 nm	290m - 330m
400 nm	> 500m
450 nm	> 500m
500 nm	400m - 500m
525 nm	220m - 280m
550 nm	150m - 210m
600 nm	90m - 130m
650 nm	< 100m

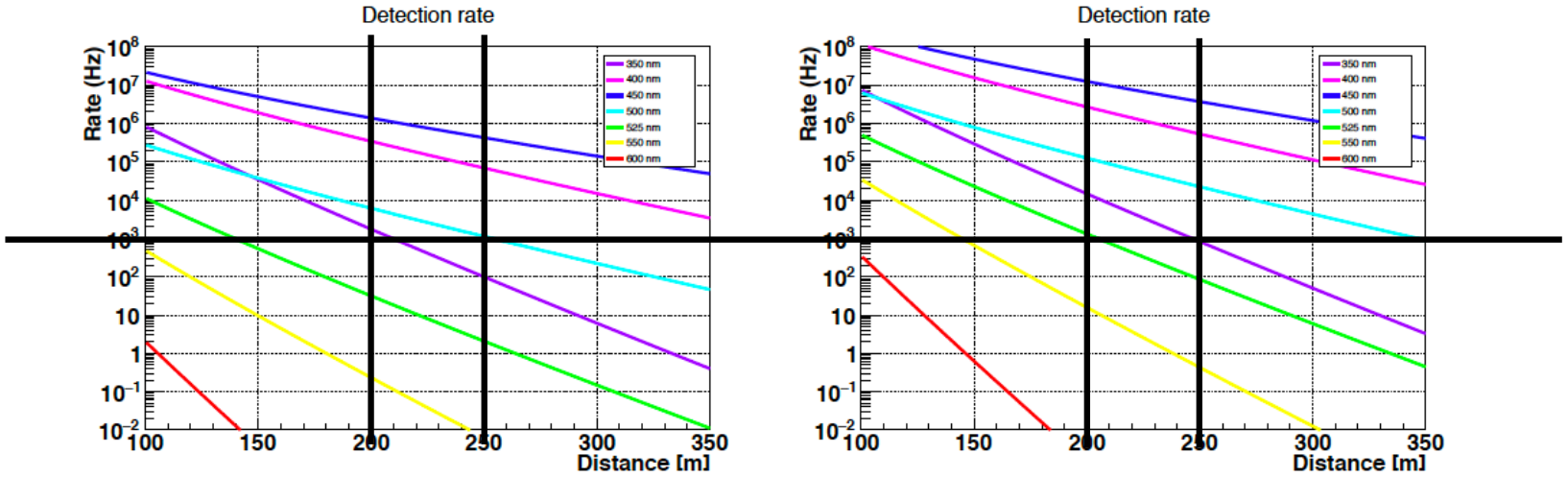


Results

Red sources can be used at full power

Green possibly at very low power – to be tested

Wavelength	200m	250m
350 nm	0.05 - 0.5 lm	1 - 10 lm
400 nm	0.0004 - 0.003 lm	0.002 - 0.01 lm
450 nm	0.0001 - 0.001 lm	0.0003 - 0.003 lm
500 nm	0.01 - 0.2 lm	0.05 - 1 lm
525 nm	1 - 30 lm	10 - 500 lm
550 nm	50 - 3000 lm	> 1000 lm
600 nm	> 1000 lm	> 1000 lm



Summary

- Light sources with $\lambda > 600$nm (red) can be used without constraint while KM3NeT/ORCA takes data
- Light sources with $\lambda < 500$nm are incompatible with data taking of KM3NeT/ORCA
- Light sources with $\lambda = 525$nm (green) might be used with low optical power (to be tested)