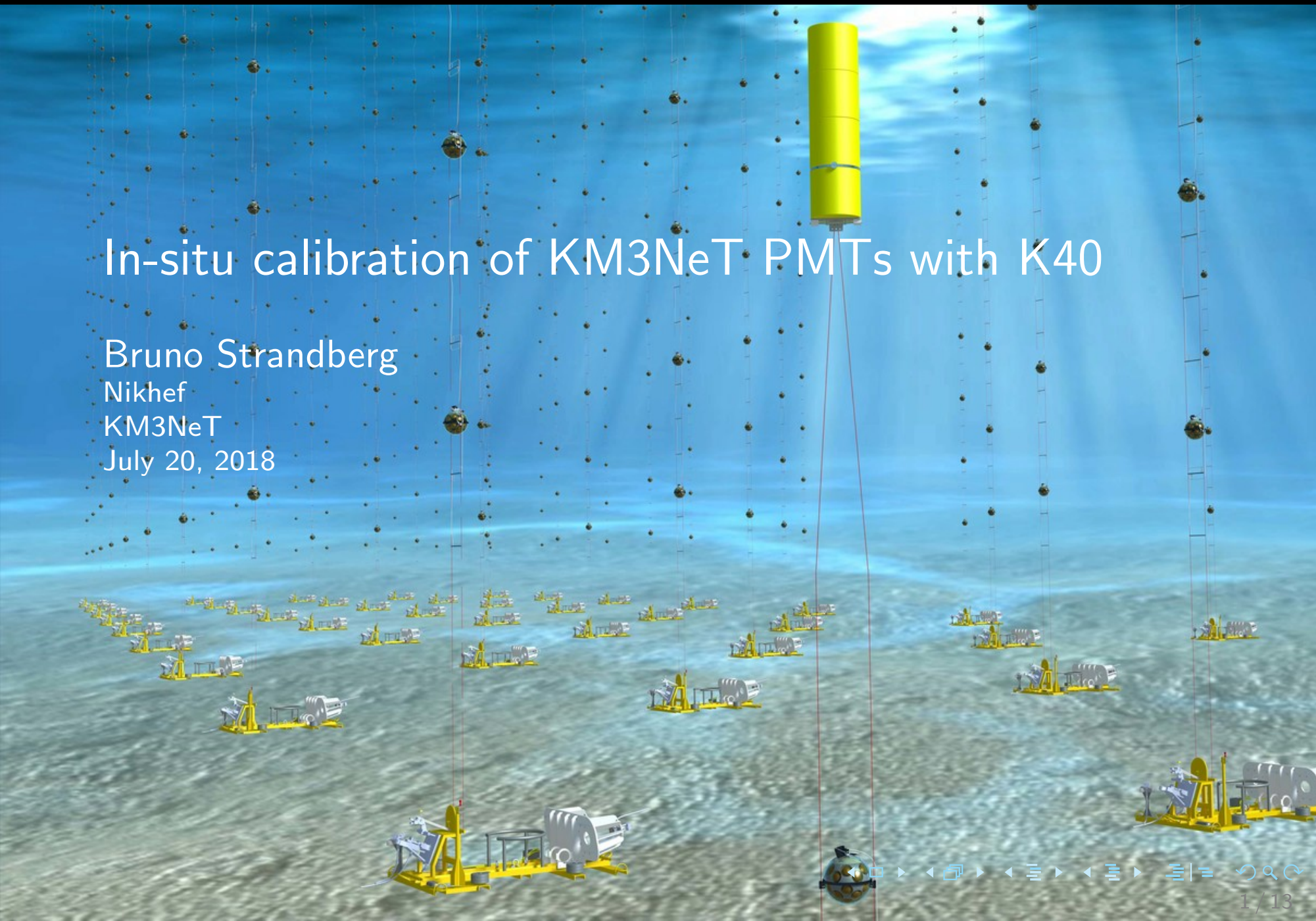

In-situ calibration of KM3NeT PMTs with K40

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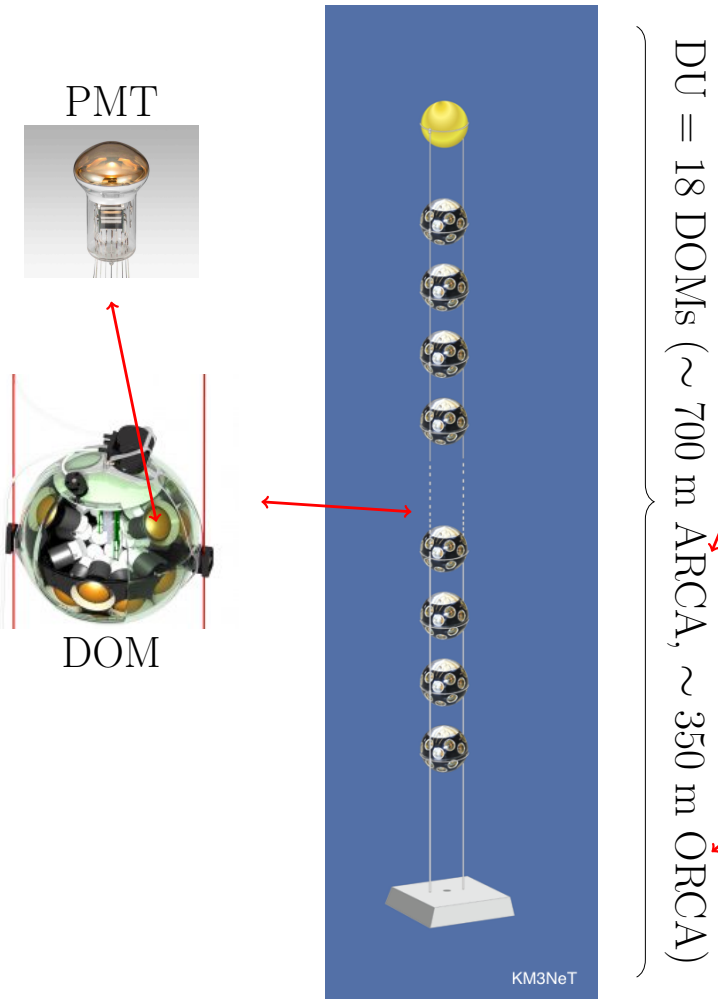
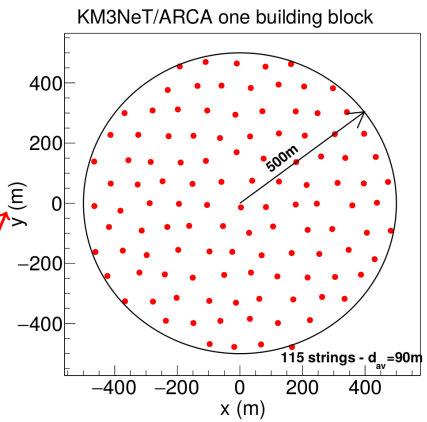
Nikhef
KM3NeT
July 20, 2018

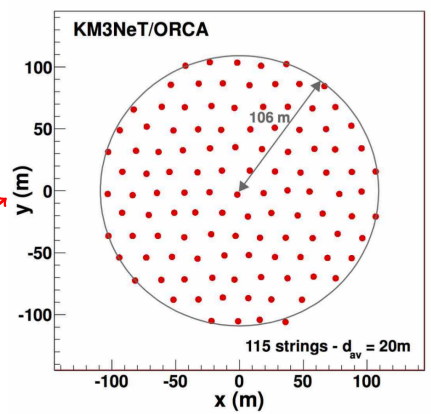
Outline

Introduction

KM3NeT - large volume neutrino telescopes at the bottom of the Mediterranean.







- ARCA - high energy ν astronomy.
- ORCA - oscillation research with atm. ν.

Introduction

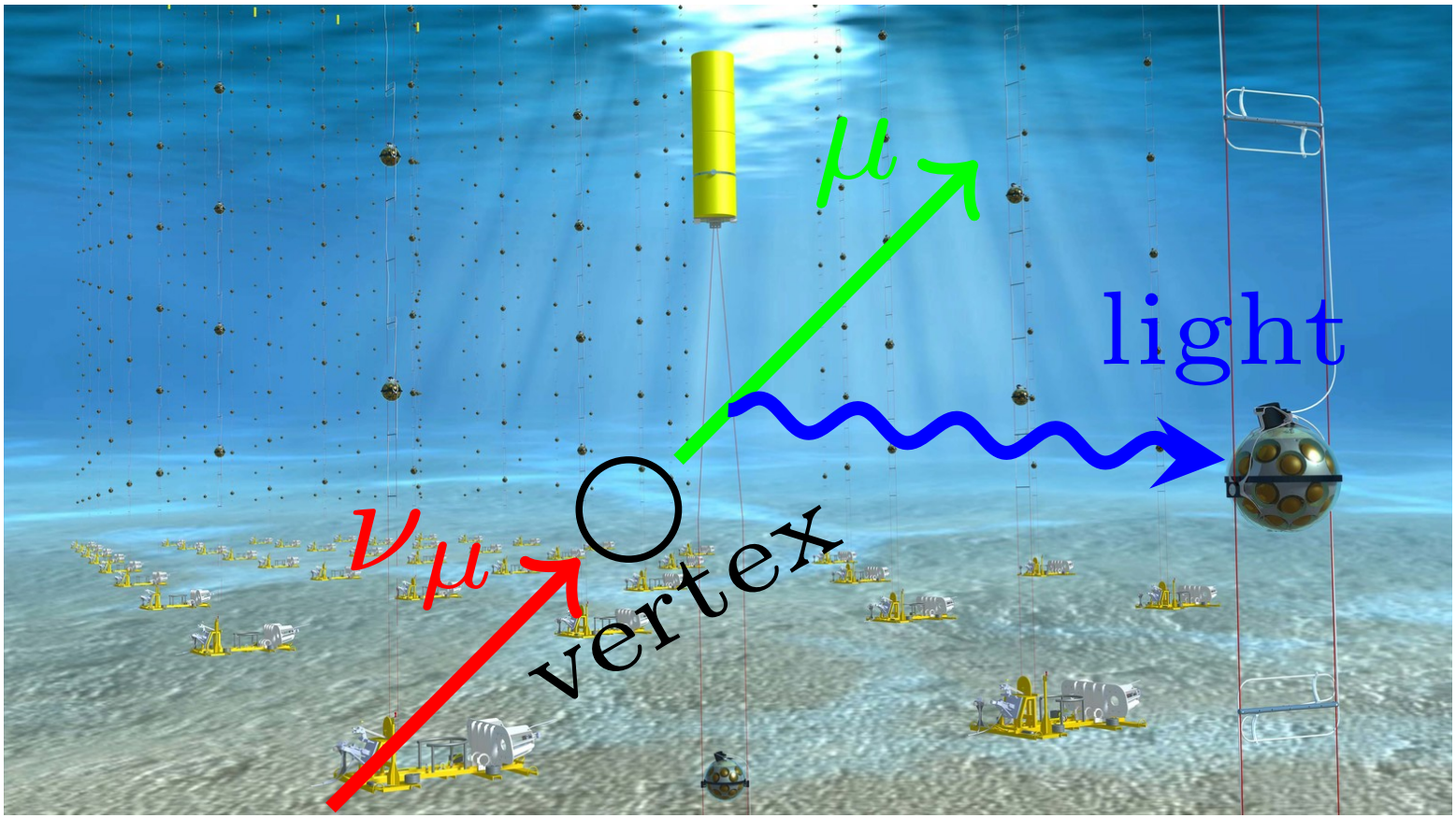
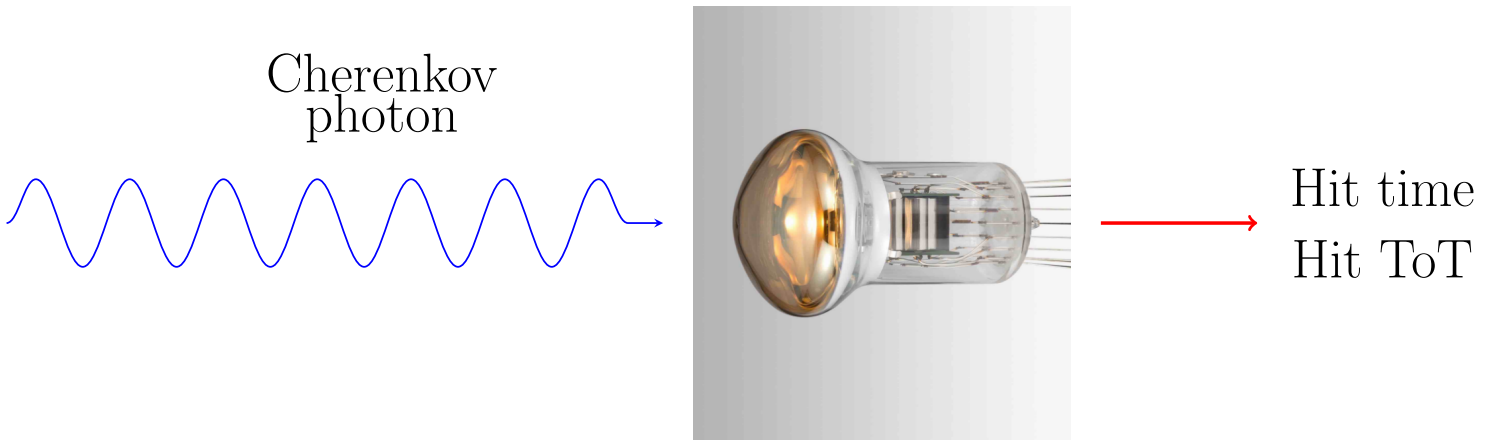


Figure: Illustration of ν detection in KM3NeT.

Introduction



ν-detection is based on Cherenkov light collection.

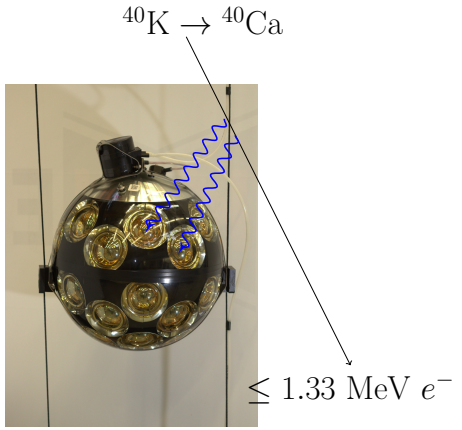
Reco @ Multi-PMT DOM level

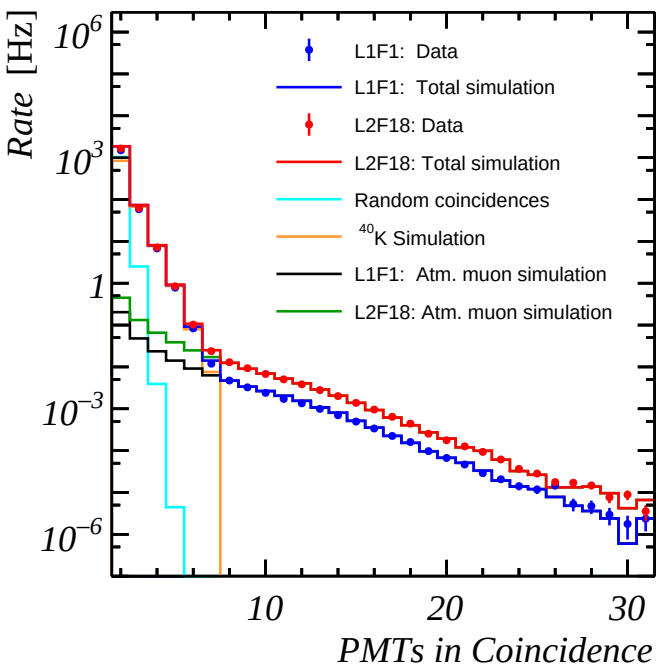
- Cherenkov direction → angle resolution.
- Hit multiplicity → energy resolution.

Reco @ PMT level

- Accurate hit time → angle resolution.
- Time-over-threshold (ToT) → energy resolution.

K40 decay signal





- K40 naturally present in sea water.
- Isotropic signal from decays.
- 2-8 PMTs hit in coincidence.

$\rightarrow$ use coincidences for calibration.

Time calibration

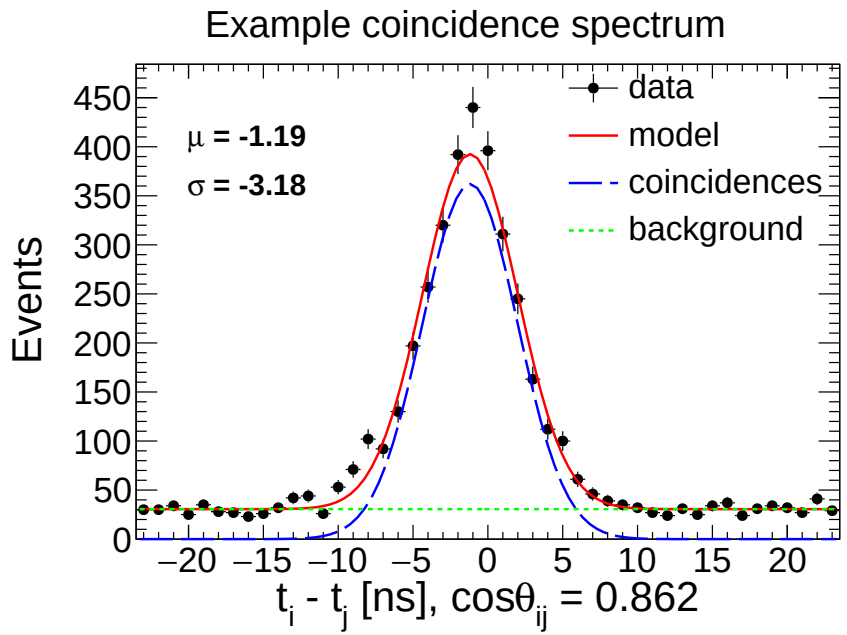


Figure: Coincidence spectrum of a PMT pair, $\theta = 30.45°$

- 31 PMTs $\rightarrow 31 \times 30/2 = 465$ pairs per DOM.
- Fit to extract $\mu_{ij} = t_i - t_j$, $i \in [1, 31]$, $i \neq j$
- Find offsets Δt_i for $i \in [2, 31]$, such that $\mu_{ij} \sim 0$.
- Find widths σ_{ij} (K40 intrinsic (0.54) + TTS).

Time calibration

Time offsets Δt_i can be used:

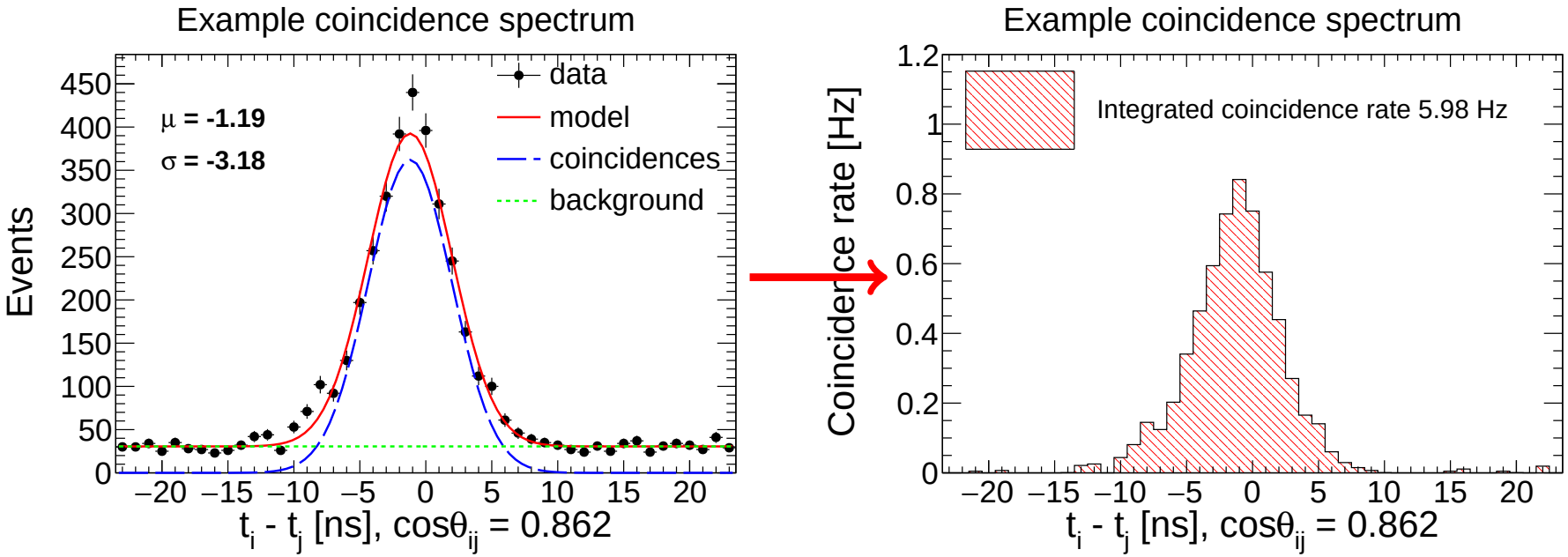
- for updating the calibration of the detector in the sea.
- as input to Monte-Carlo to match it to data.

Width σ_{ij} can be used:

- as input to Monte-Carlo to match it to data.

$\rightarrow$ Timing calibration in the order of 1 ns!

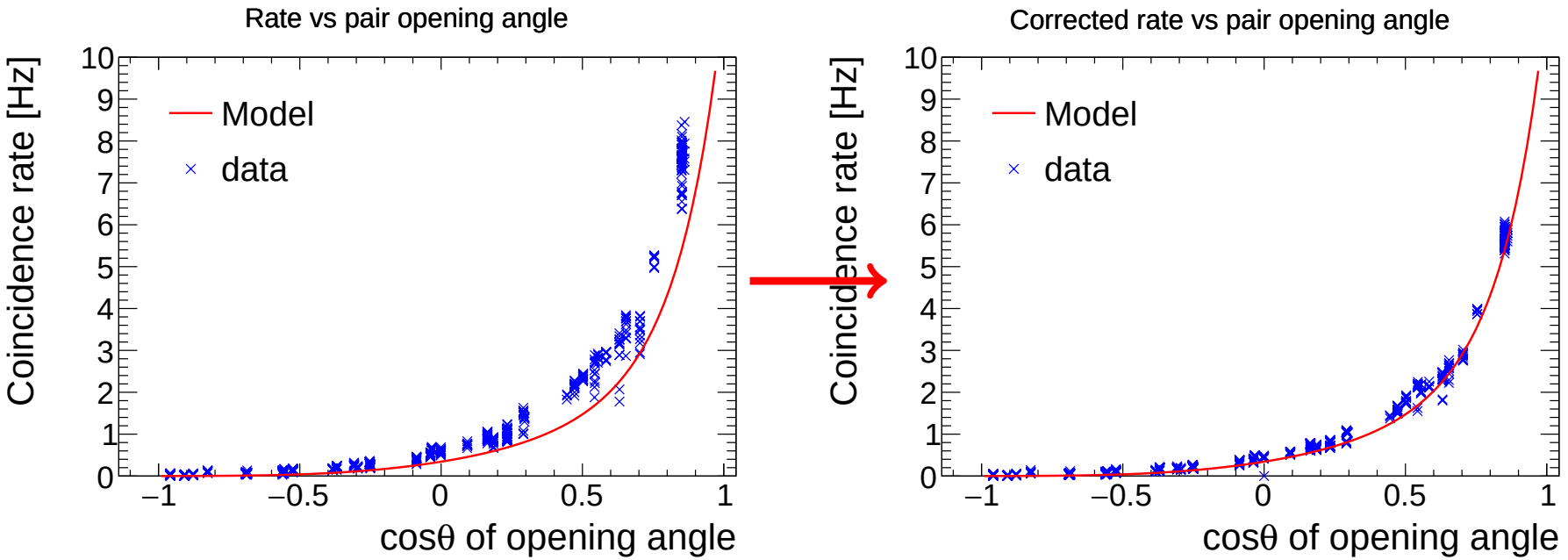
PMT efficiency



- Subtract backround from coincidence spectrum.
- Divide by run time.

Coincidence rate R per each PMT pair $\rightarrow$ plot R vs pair opening angle θ.

PMT efficiency



- 31 PMTs $\rightarrow 31 \times 30/2 = 465$ pairs per DOM.
- Extract rate R_{ij}, $i \in [1, 31]$, $i \neq j$
- Find c_i, c_j, such that $c_i c_j R_{ij} \simeq Model(cos\theta_{ij})$

c_i are PMT relative efficiencies.

PMT efficiency

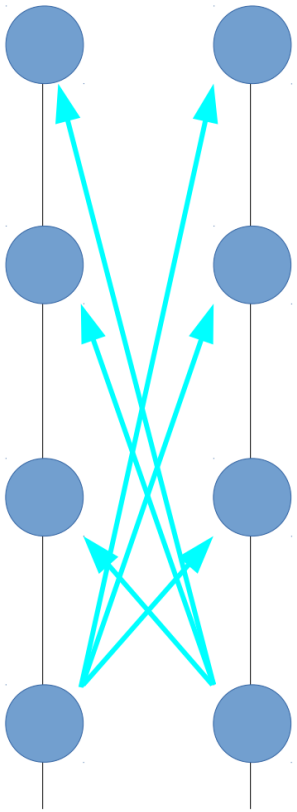
Relative efficiencies c_i can be used:

- To match Monte Carlo to data.
- As guidance for PMT high-voltage tuning.

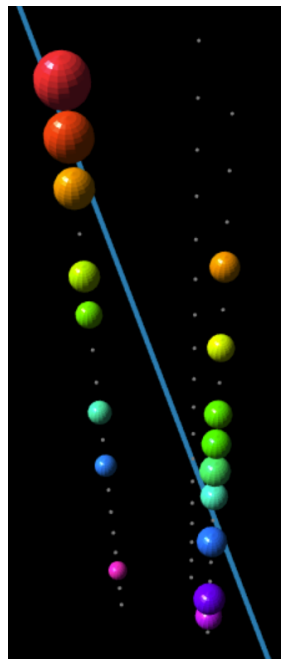
Input to c_i determination:

- K40 abundance in sea water.
- Detector geometry in simulation.

Cross-checks:



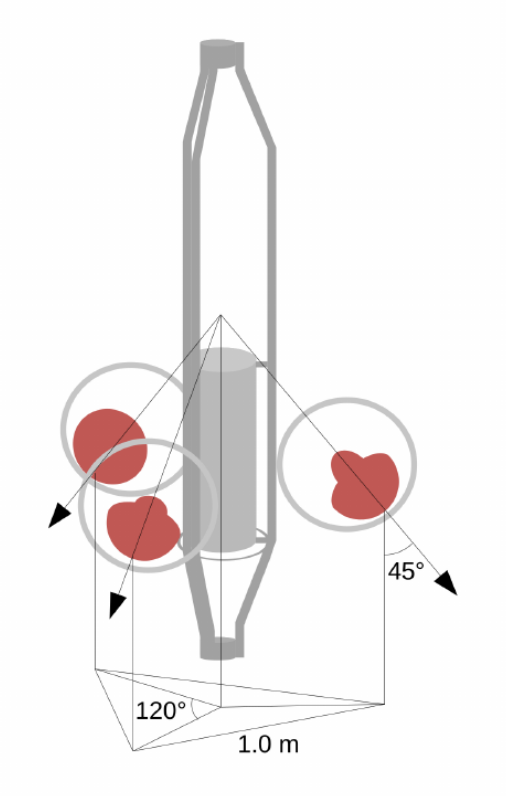
Nanobeacons → time cal.



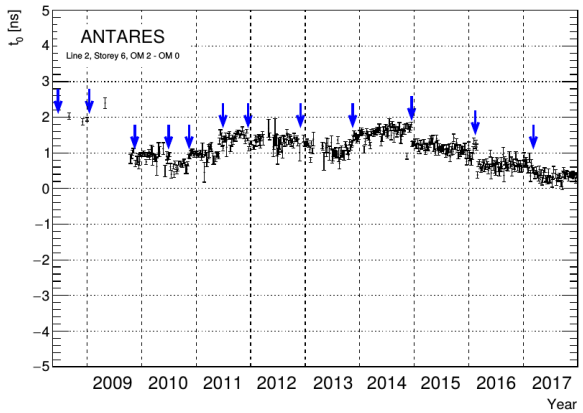
Atm. muons → eff. cal.

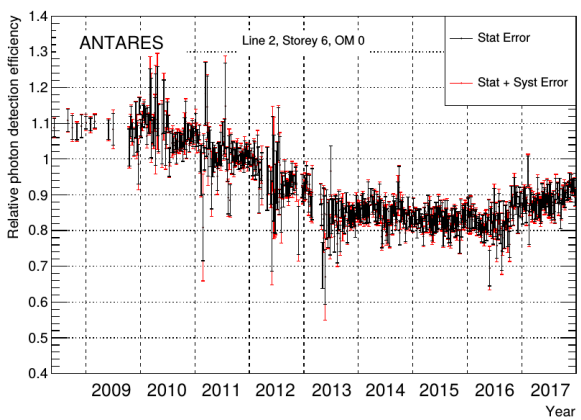
Memories...

K40 calibrations have been successfully used in ANATRES for $\sim$ 10 years.



ANTARES three-DOM floor.





ANTARES Δt_i and c_i.

Summary

- K40 decays can be used for accurate time calibration.
- K40 decays provide info about PMT relative efficiencies.
- K40 calibrations can be cross checked against other analyses.
- Has been successfully used in ANTARES.

Thank you for your attention!

Figures from:

1. `www.km3net.org`
2. Letter of Intent for KM3NeT 2.0
3. K. Melis PhD thesis (2019).
4. M. Jongen nanobeacon analysis.
5. Long-term monitoring of the ANTARES optical module efficiencies using 40K decays in sea water `https://arxiv.org/pdf/1805.08675.pdf`.