Technical University of Munich

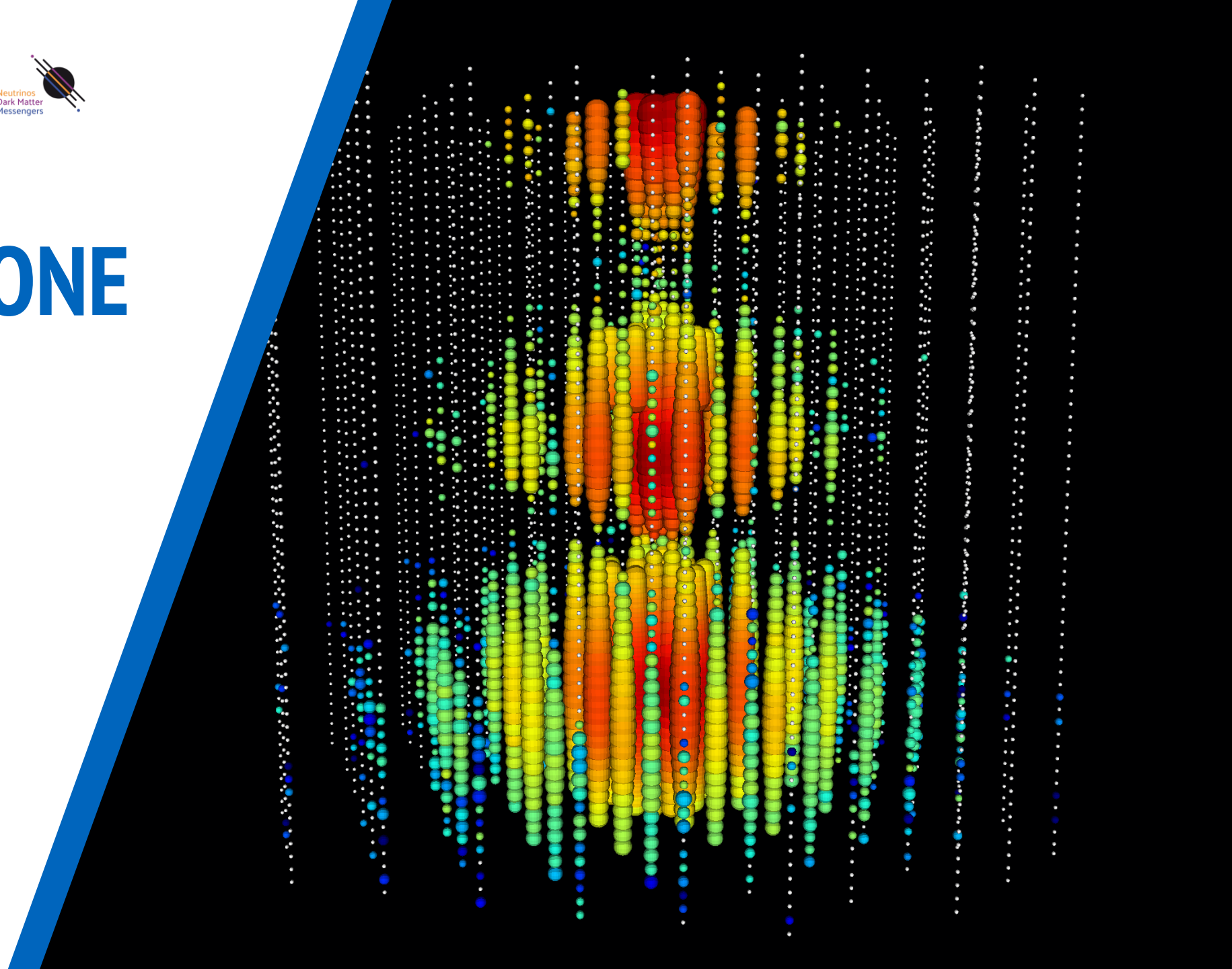
Max-Planck-Institut für Physik

SFB 1258 Neutrinos Dark Matter Messengers

IceCube South Pole Neutrino Observatory

# POCAM in P-ONE

## Instrument overview



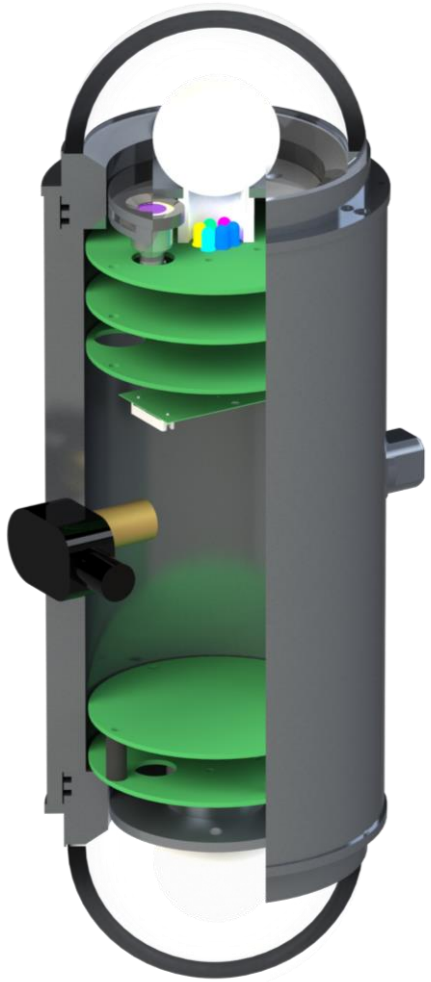
P-ONE General Meeting

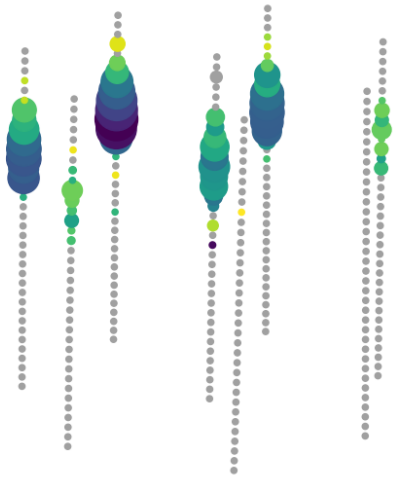
**Felix Henningsen**

Max-Planck Institute Munich / TU Munich

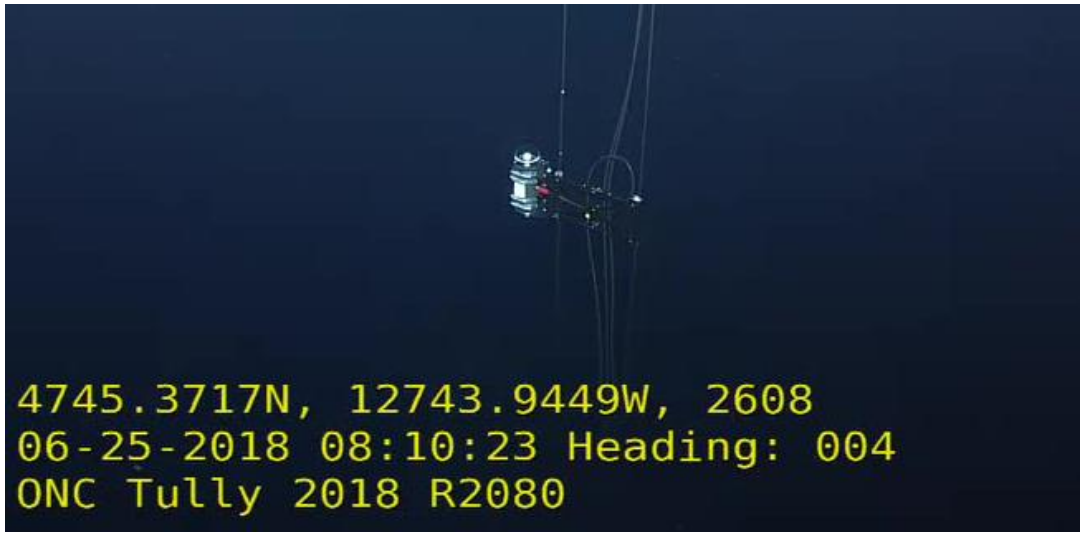
16.12.2020

# The Precision Optical Calibration Module





- POCAM = Precision Optical Calibration Module
- Isotropic, nanosecond, self-monitored light source
- Two previous deployments
  - GVD, Lake Baikal, 1000m (2017)
  - STRAW Experiment, North-east Pacific Ocean, 2600m (2018)
- Planned for the IceCube Upgrade (2022)

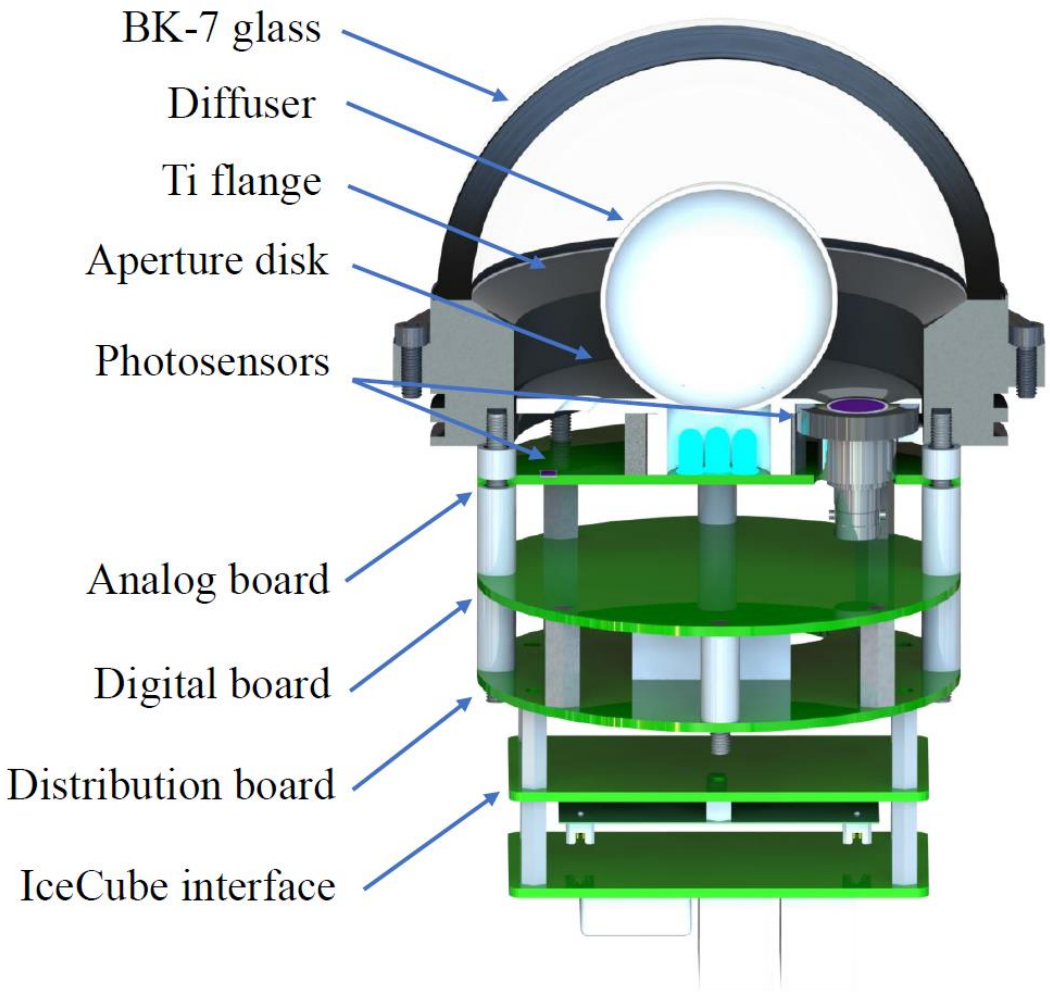


# The Precision Optical Calibration Module

- POCAM = Precision Optical Calibration Module
- Isotropic, nanosecond, self-monitored light source
- Two previous deployments
  - GVD, Lake Baikal, 1000m (2017)
  - STRAW Experiment, Mediterranean Ocean, 2600m (2018)
- Part of the IceCube Upgrade (2022)

https://doi.org/10.1088/1748-0221/15/07/P07031

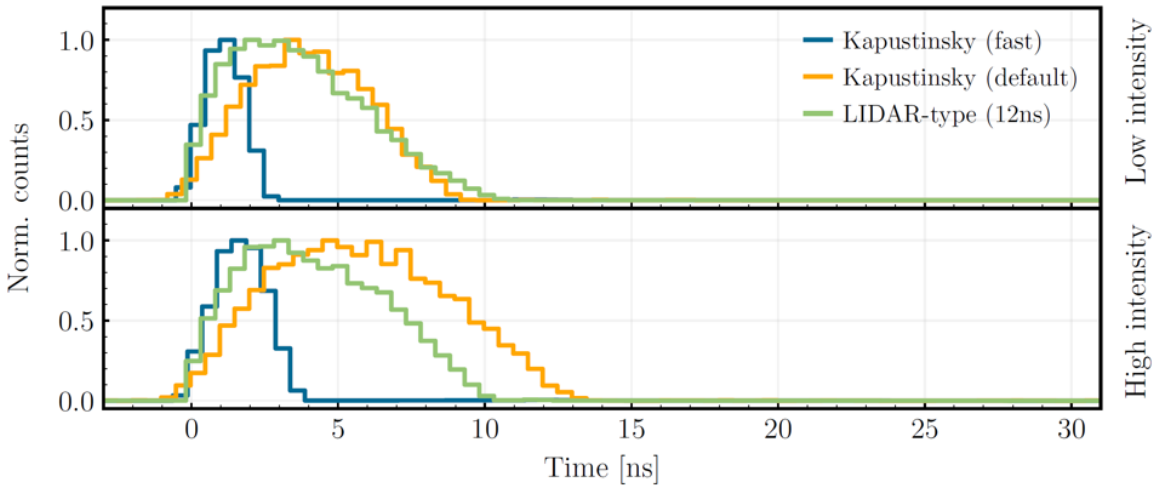
# The Precision Optical Calibration Module

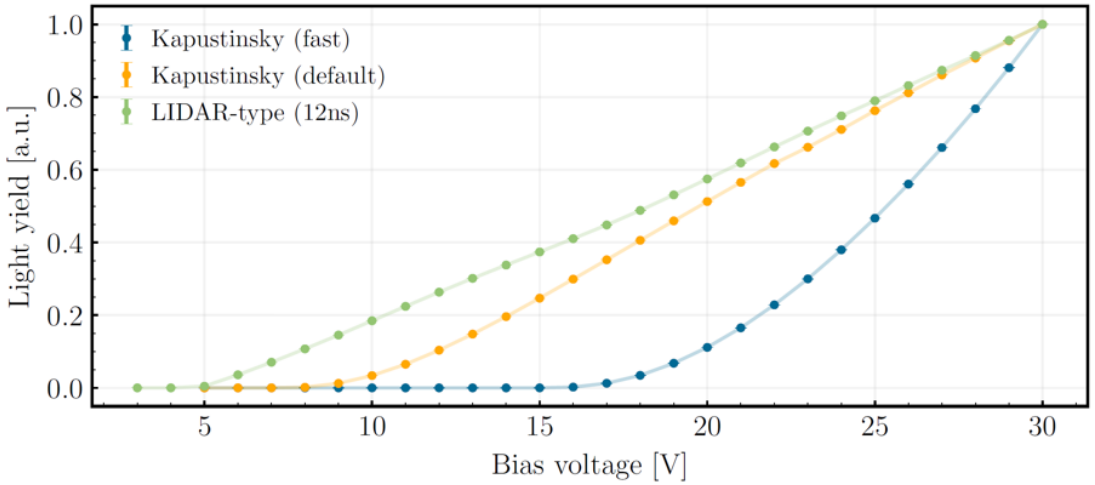



- **Housing:** Titanium with BK-7 glass hemispheres
- **Integrator:** Optical PTFE sphere (machined at TUM)
- **Self-monitoring:** Photodiode and SiPM
- **Flashing:** LED- and Laser drivers
  - Intensity: 6e7 – 1e11 photons / pulse
  - Pulse width: 1.4 – 15ns
  - Spectrum: 365, 405, 450, 465, 520nm
- **Electronics:**
  - Analog-, digital- and distribution board for internal control
  - Modular backend to adapt to telescope DAQ

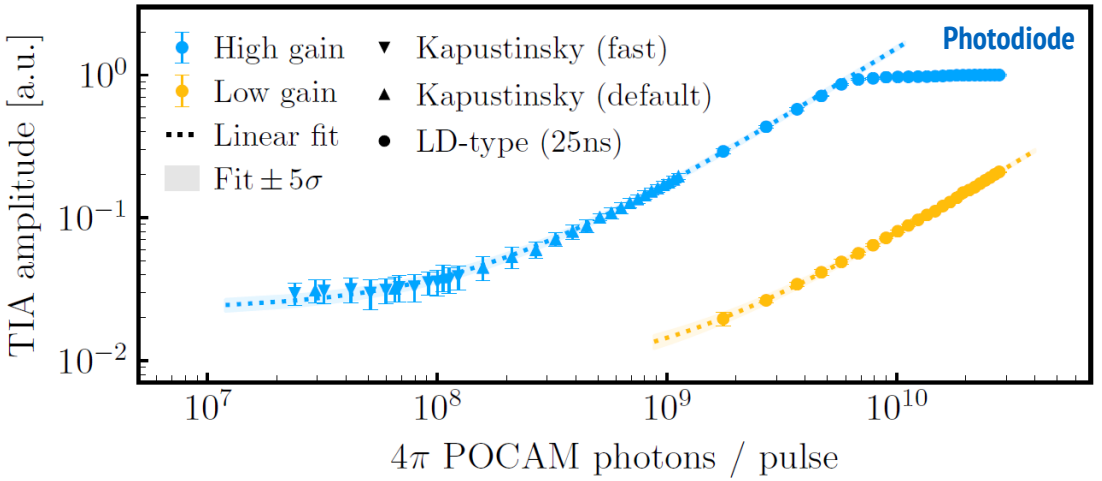
# The Precision Optical Calibration Module

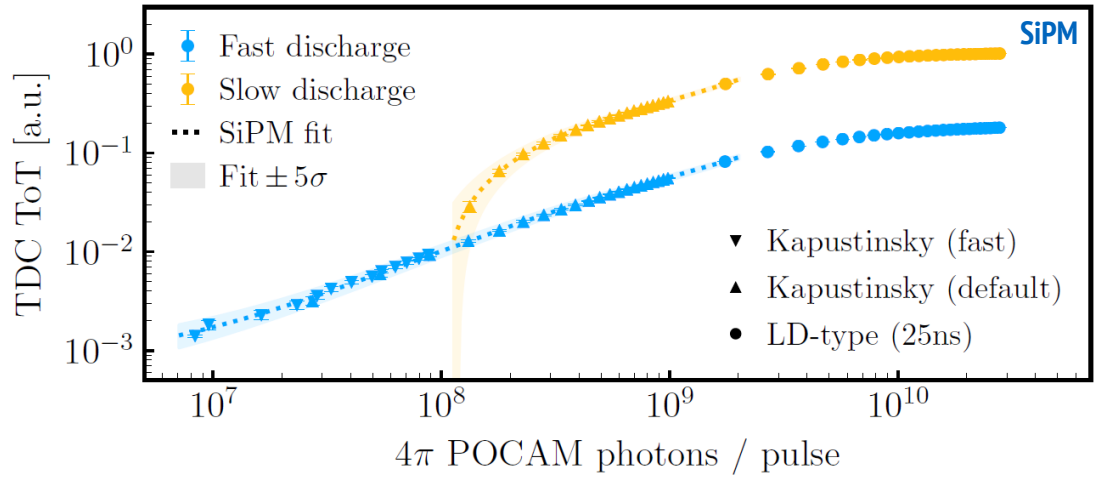
## Flasher performance



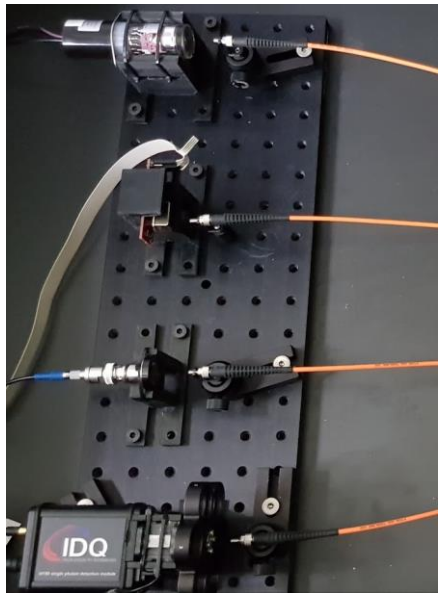



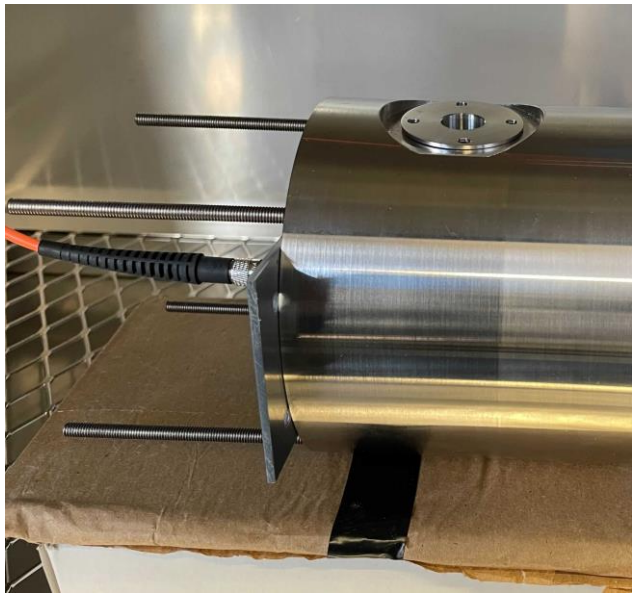

## Sensor performance

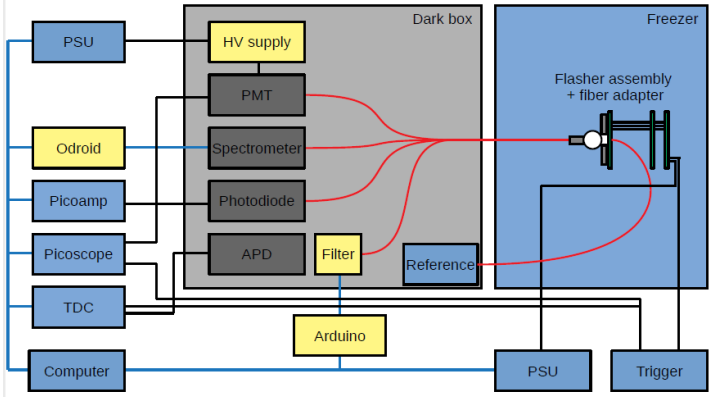


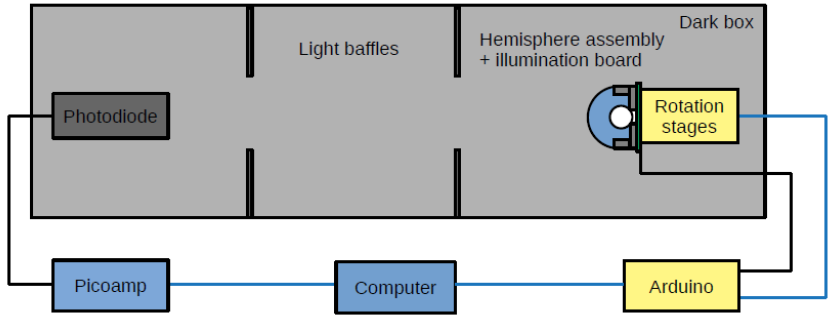



# Automated calibration





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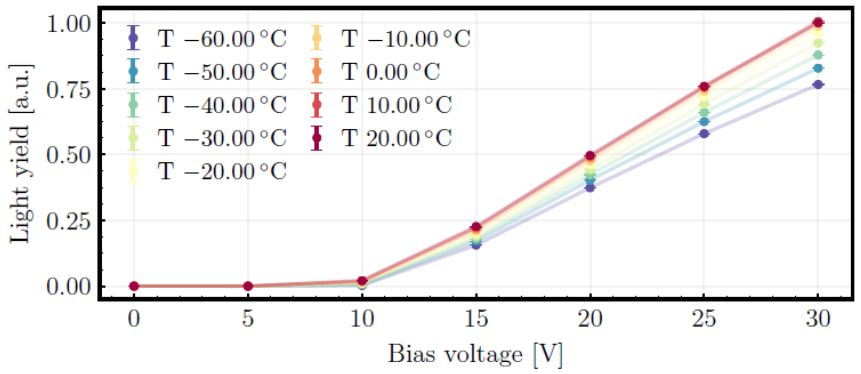
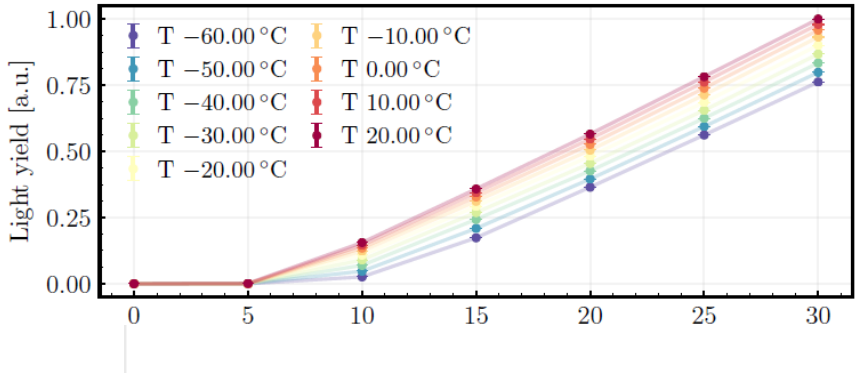
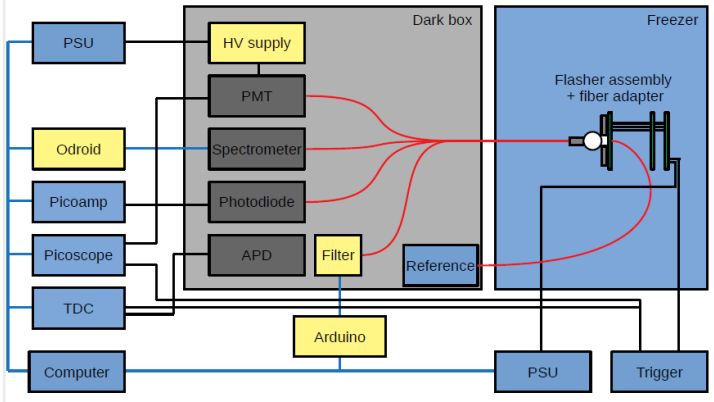
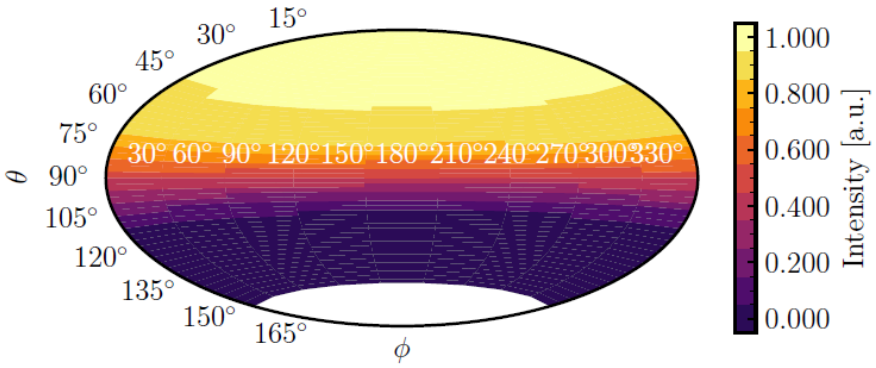
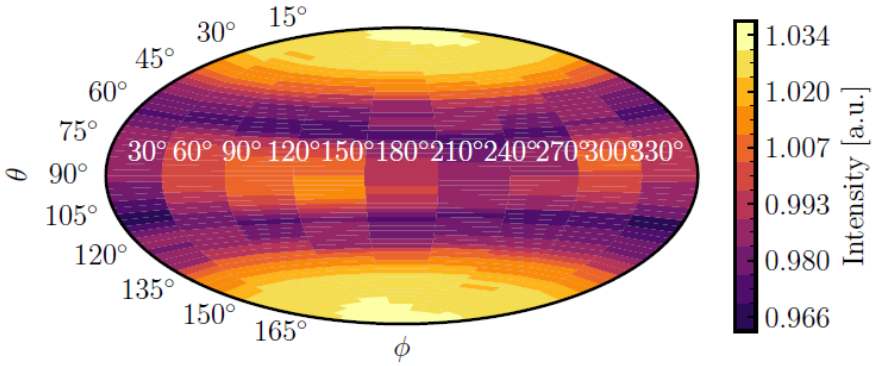
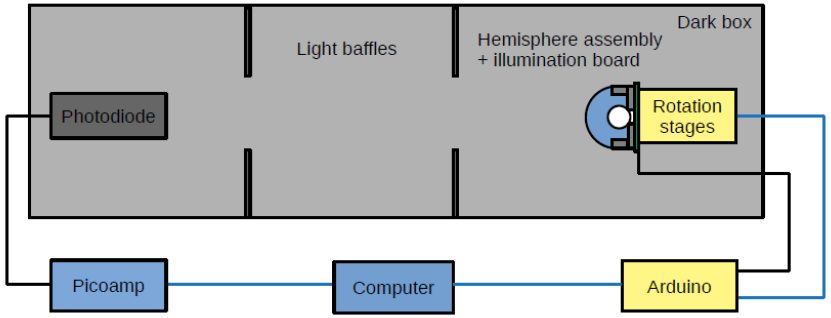


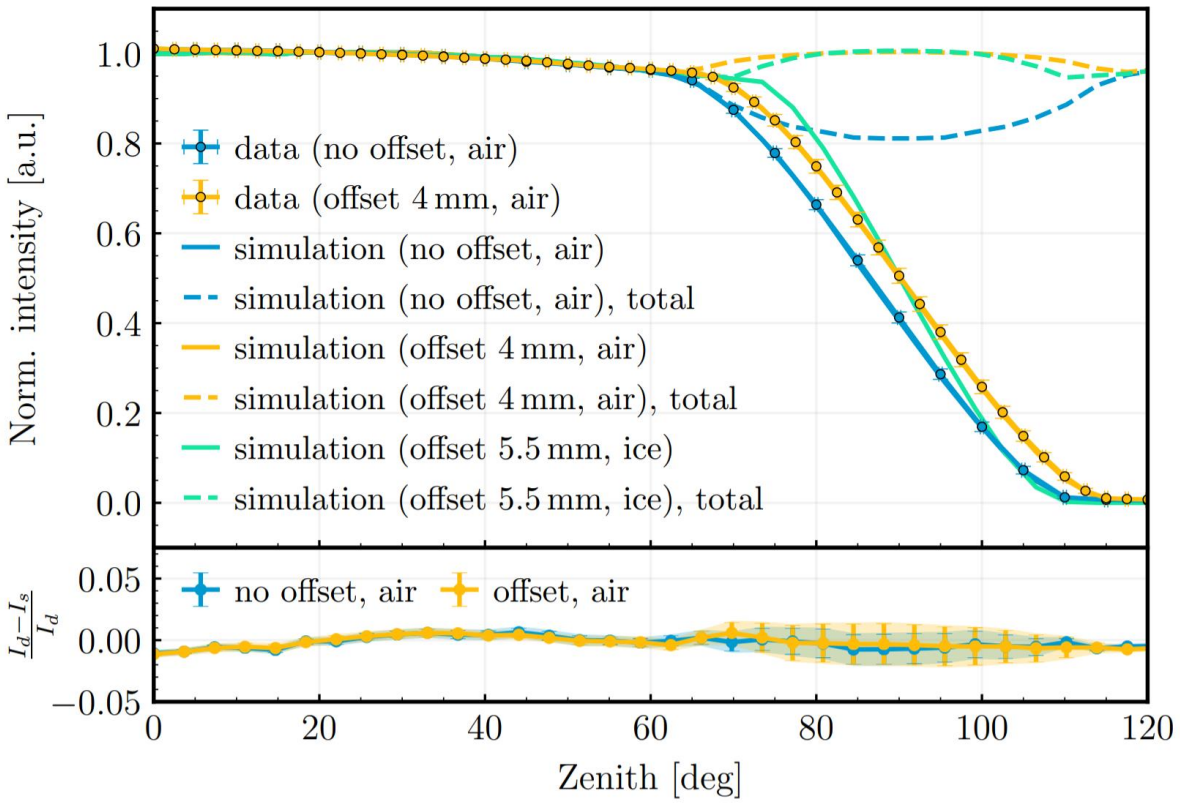



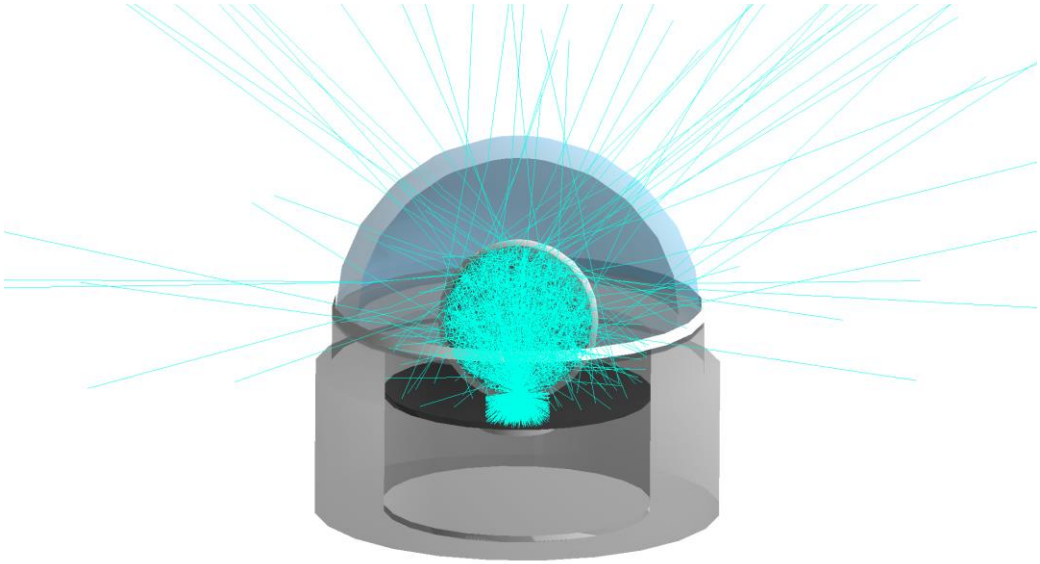



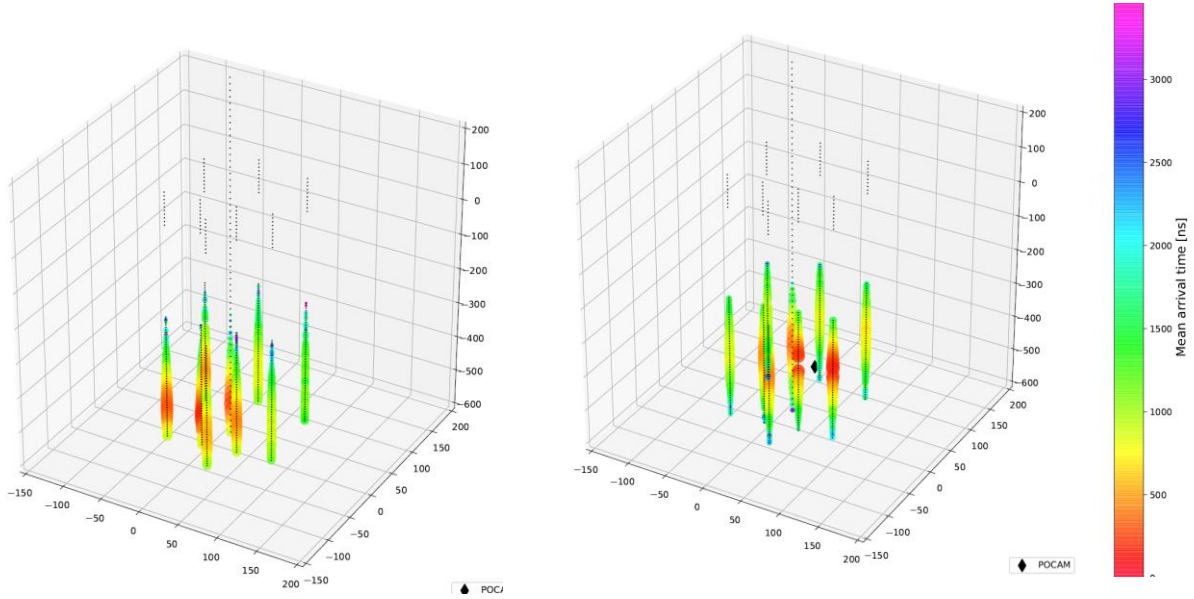
# Device simulation

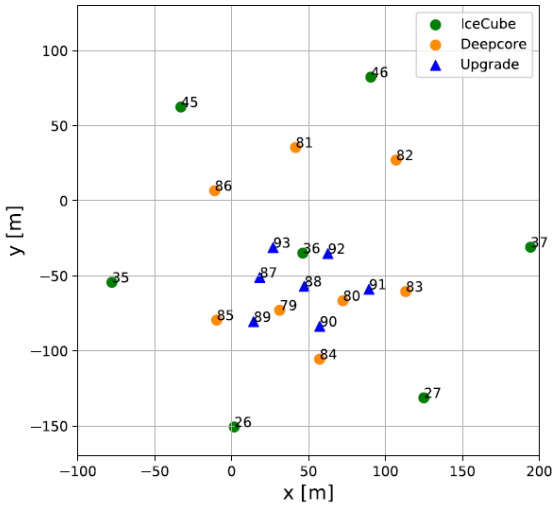



- GEANT4 simulation of device matches lab measurements
- Enabled improvements of isotropy by tweaking mounting and material parameters

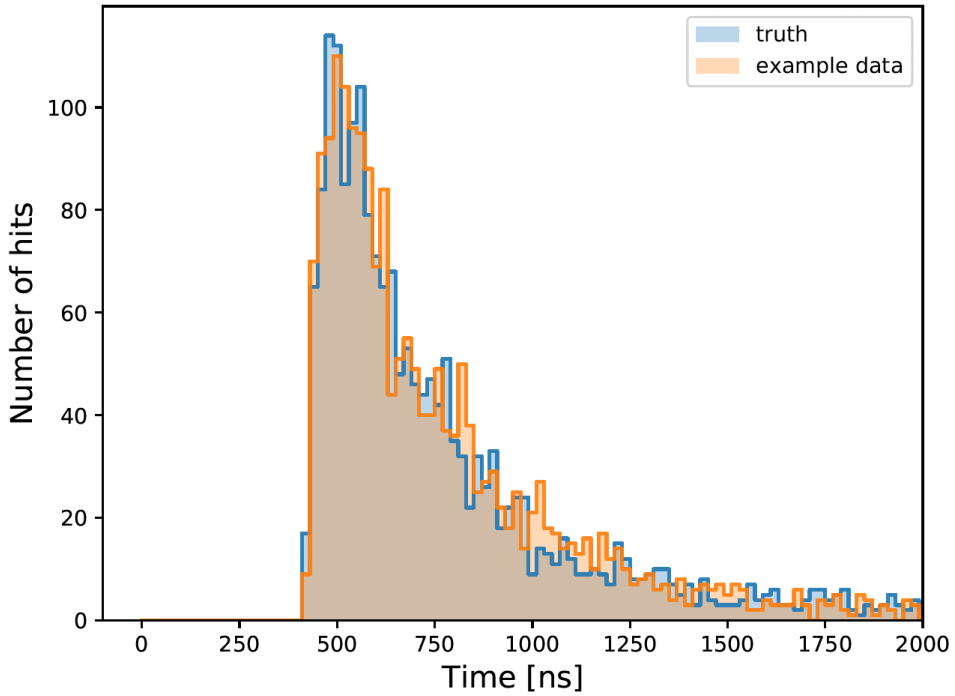


# Simulation setup

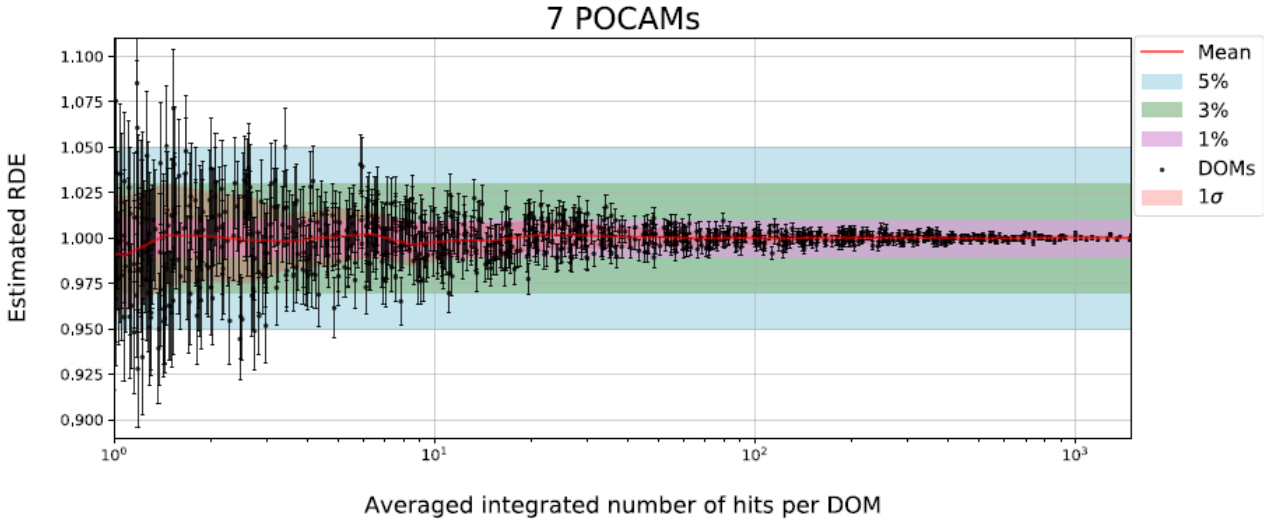


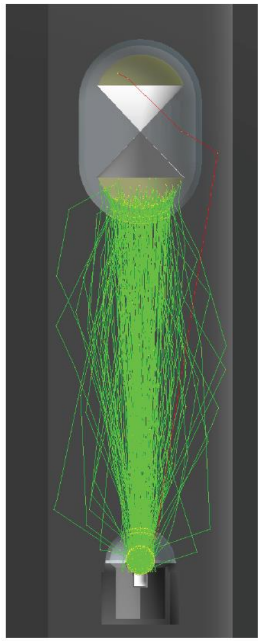



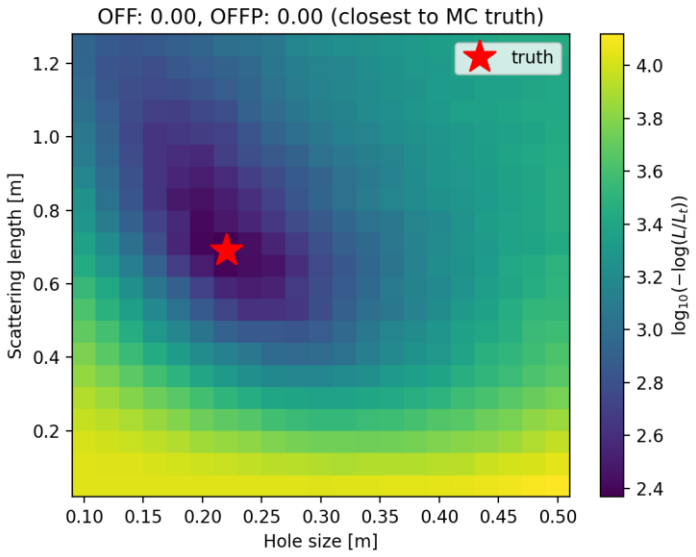

- IceCube simulation chain for the Upgrade
- Primary goal is to tackle potential calibration sensitivity
- Secondary goal is to identify run plans and best positioning
- Simulation structure can be adapted for water easily



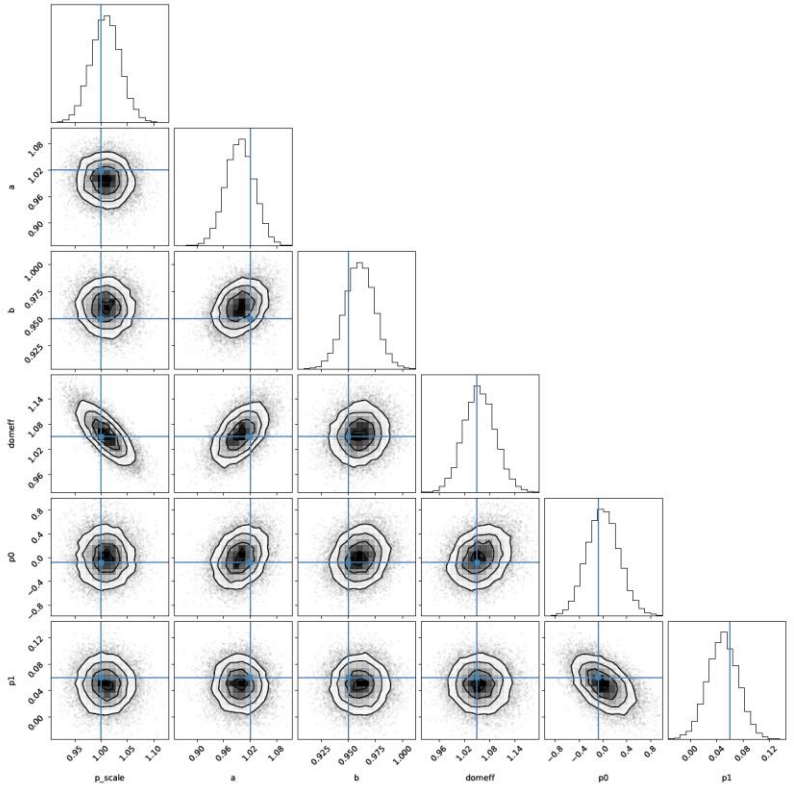
# Physics studies



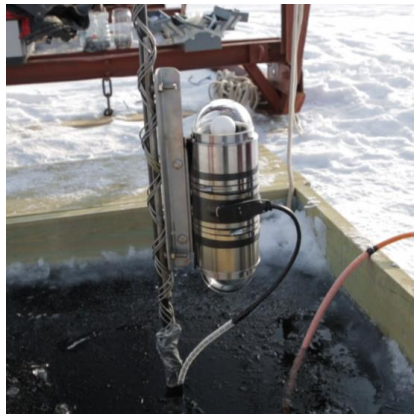



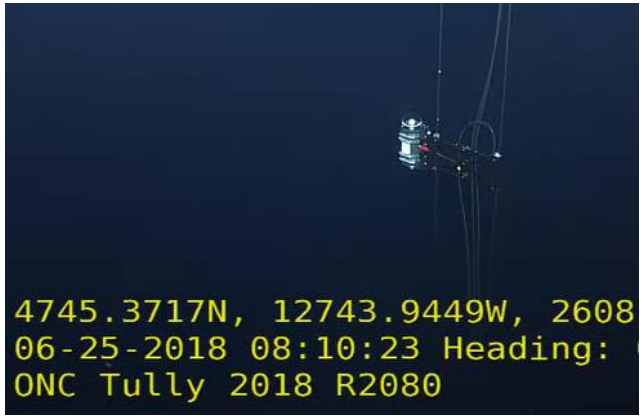


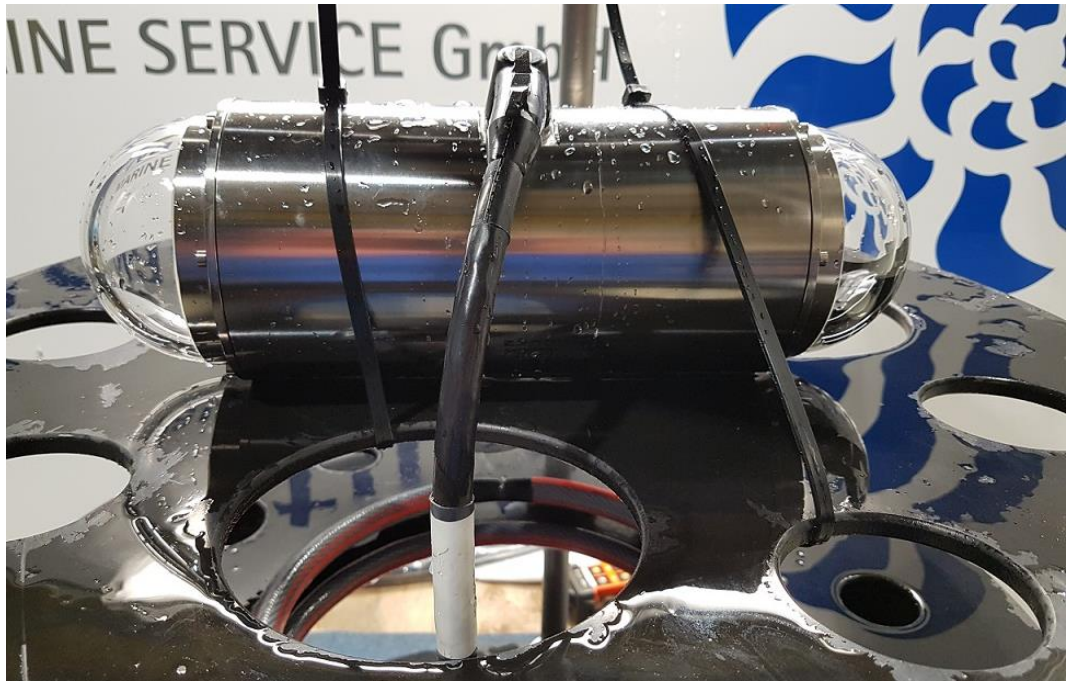

- Simulation studies currently IceCube focussed
- Primary goal is to tackle potential calibration sensitivity
- Secondary goal is to identify run plans and best positioning
- Simulation / analysis chain can be adapted to water



# The Precision Optical Calibration Module





https://iopscience.iop.org/article/10.1088/1748-0221/15/07/P07031

- Tested for high pressure
  - GVD (1000m water depth)
  - STRAW (2600m water depth)
  - Pressure chamber (7000m water equivalent depth)
- Tested for vibrations
  - ISO 13628-6 (5-150Hz / 5G, 3-axis shocks / 10G)
- Tested for low temperature
  - IceCube Upgrade (-80°C <-> RT stress, -40°C operation)

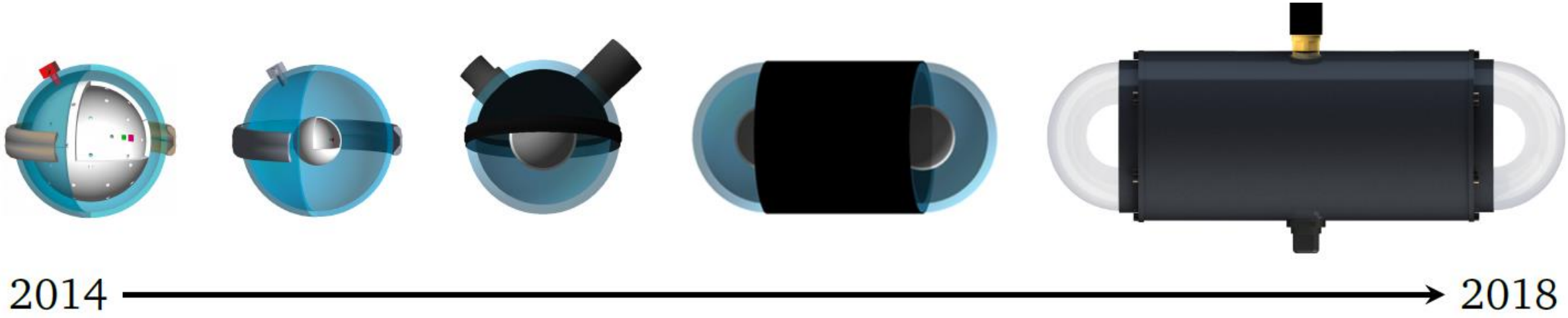
# What's next?

- Simulation work on Upgrade is on-going
  - Adaptation to water can be done!
- Device design frozen early next year
- Potential adaptations / brainstorming for P-ONE
  - can start now
  - maybe include acoustics?

**Thanks!**

# Backup

# POCAM history timeline




**2013:** self-monitored light source idea initially emerged from discussions of Chris Wendt and Elisa

**2014:** isotropy idea and simulations showed feasibility

**2015:** prototyping showed spherical version very optimistic

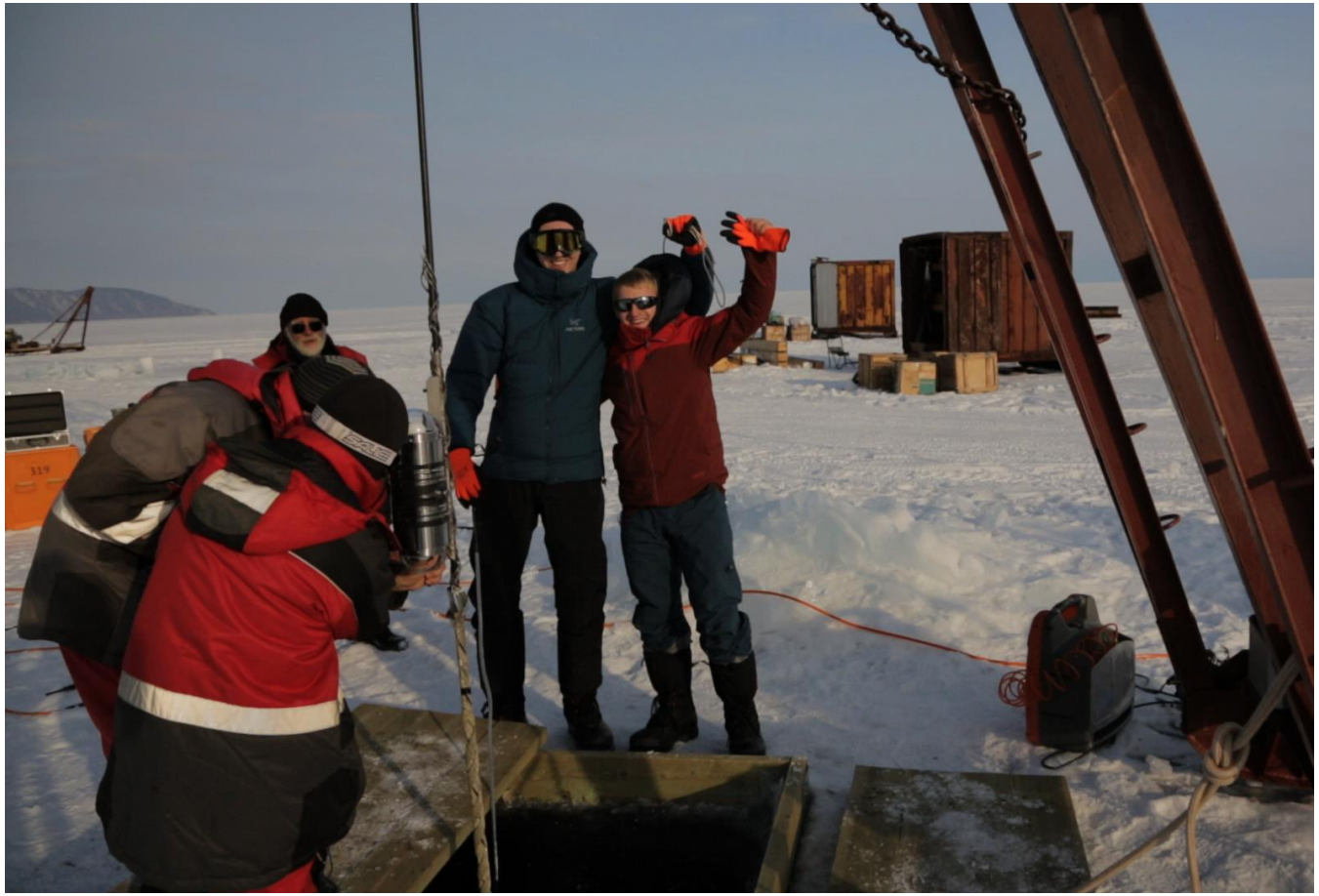
**2016:** cylindrical design was introduced

**2017:** first functional prototype goes to GVD

**2018:** 3x POCAMv2 goes to STRAW

# GVD

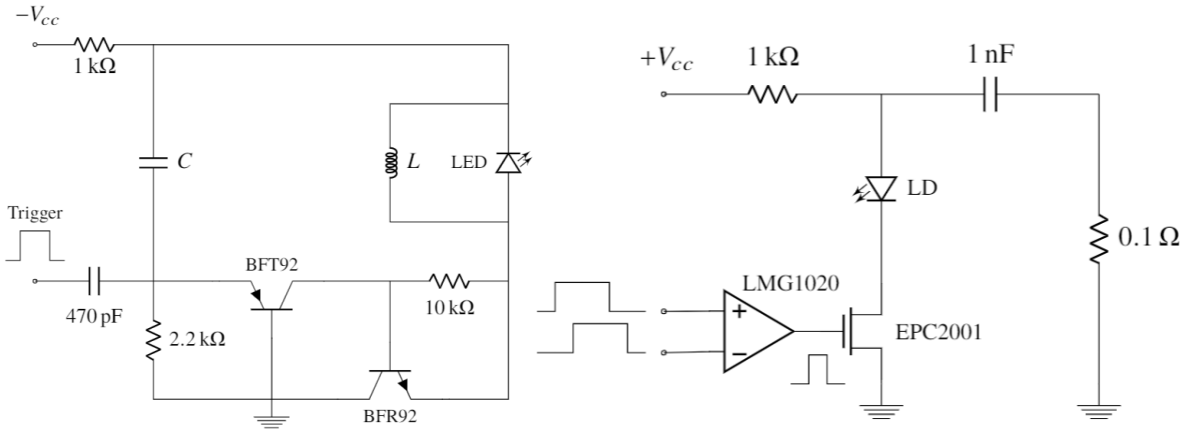
- Deployed for one-year (2017-2018)

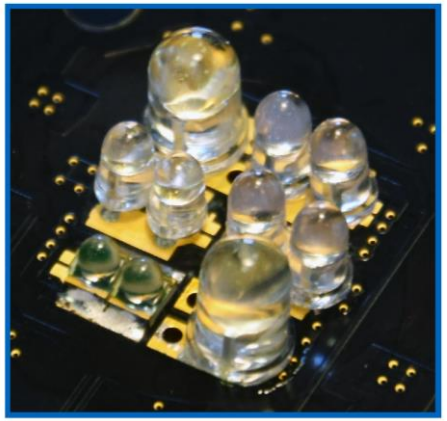




Photos: J. Thompson

# POCAM stuff



Light Yield

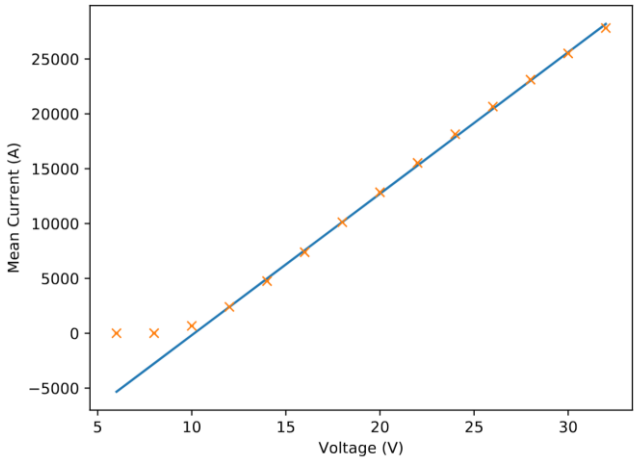
Wavelength

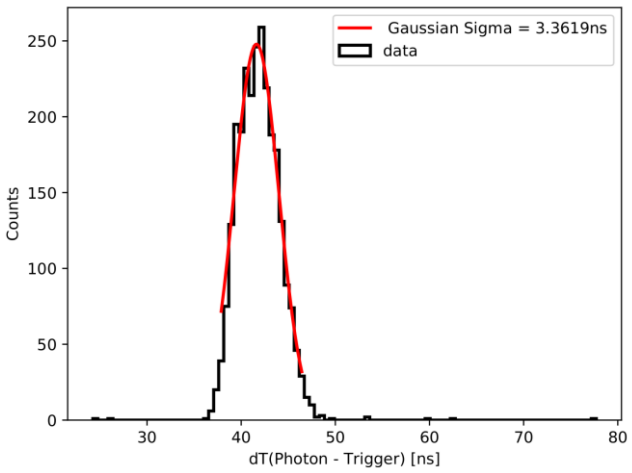
Pulsers

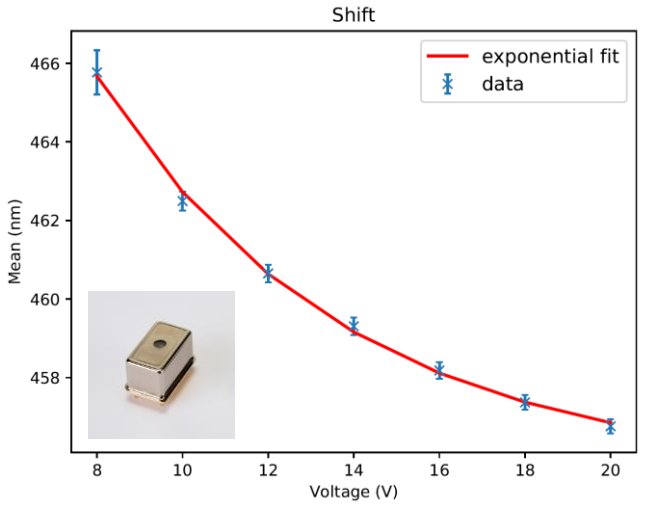
Timing

POCAM

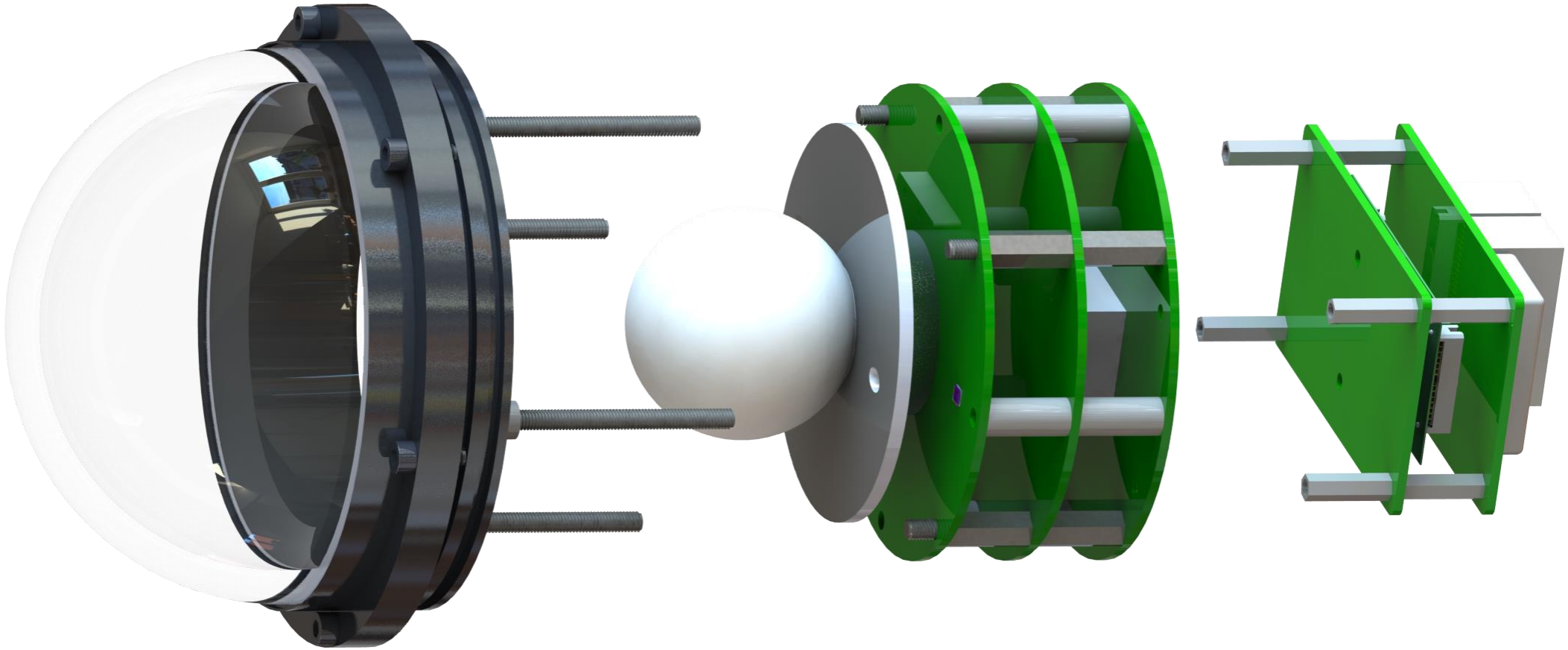
Verification



# POCAM-ICU



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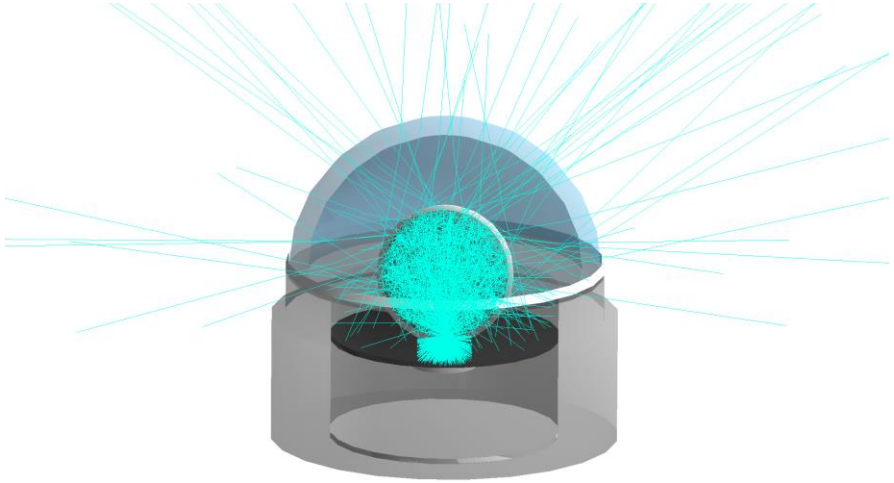

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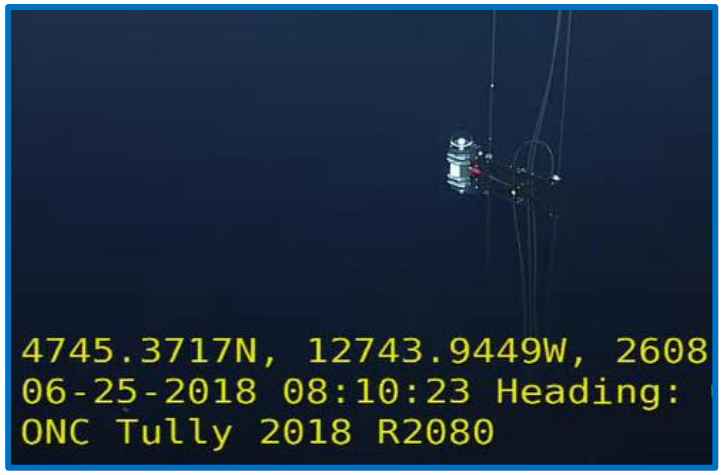
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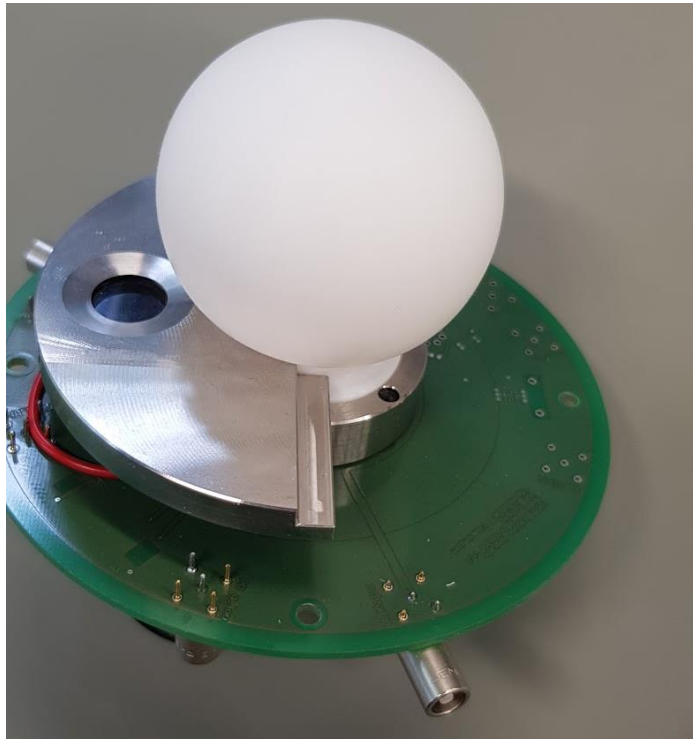
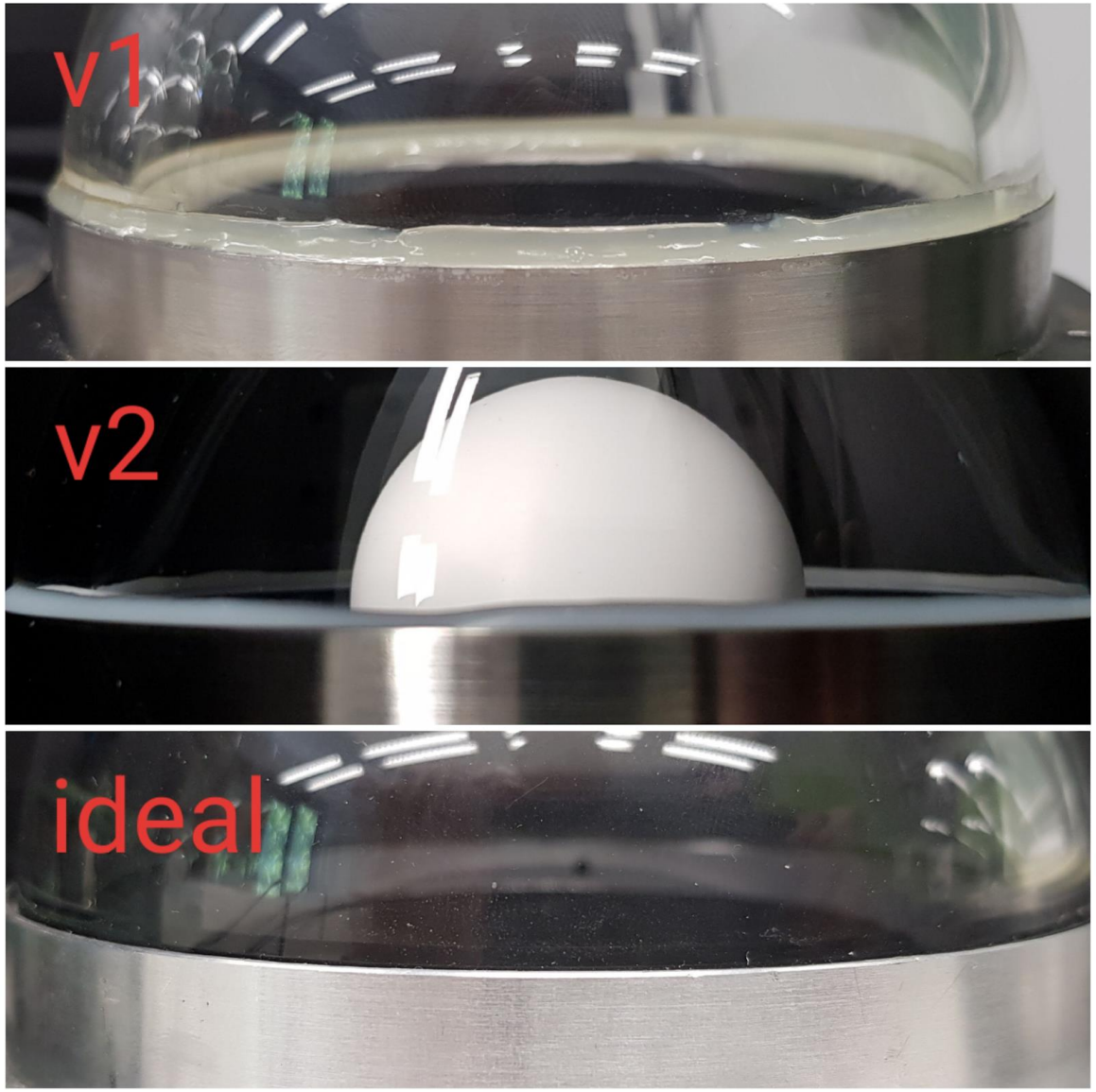
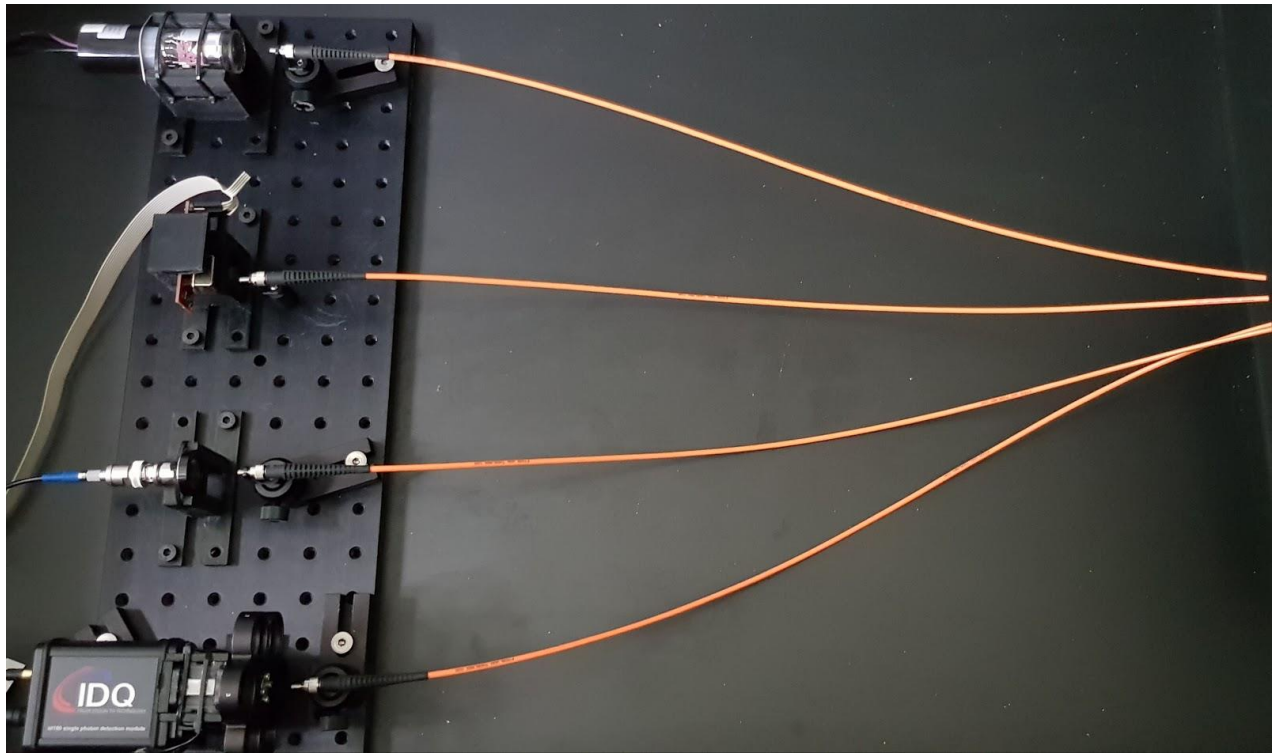
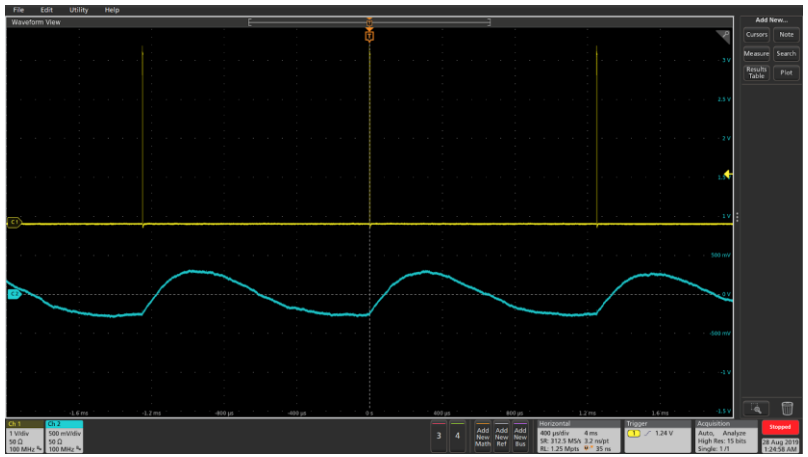
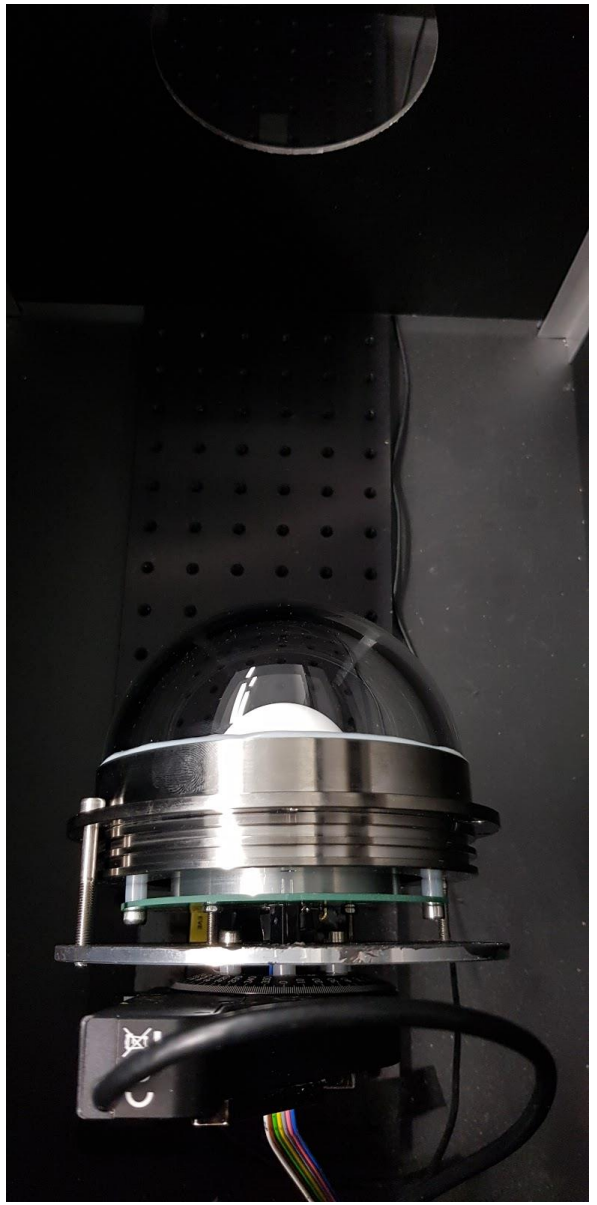


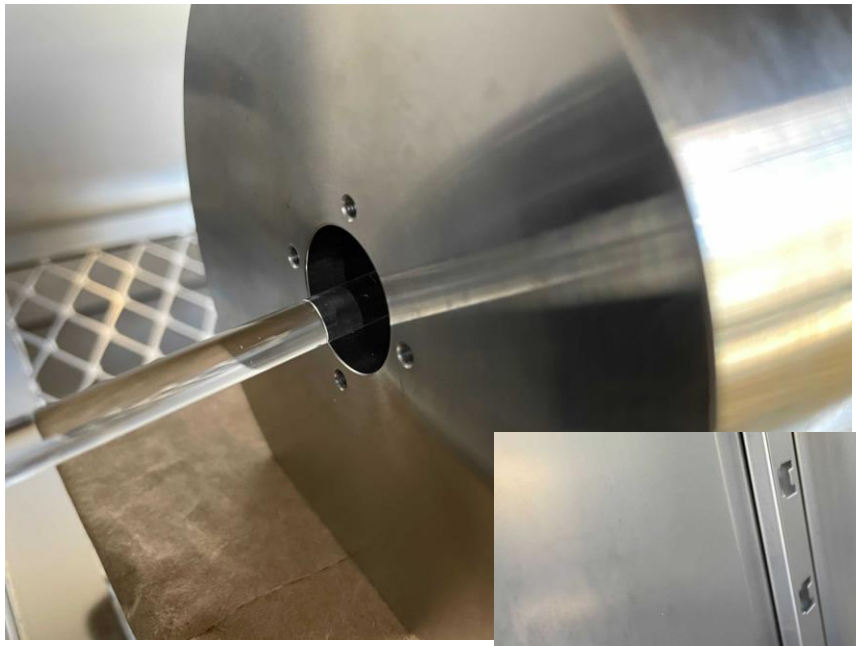

v1
v2
ideal

# POCAM-ICU



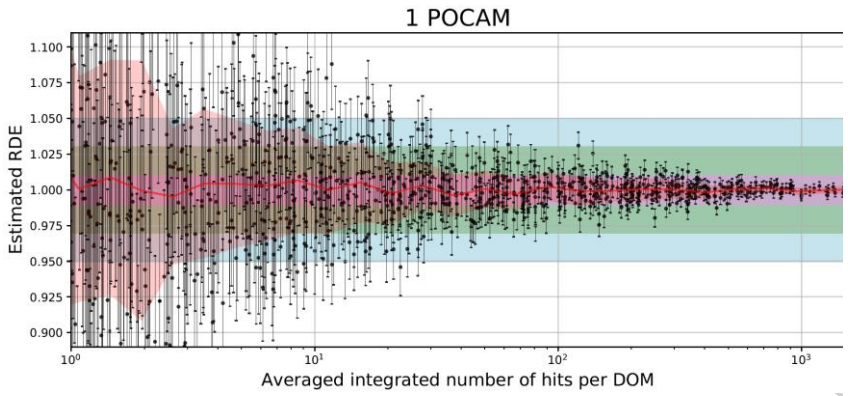


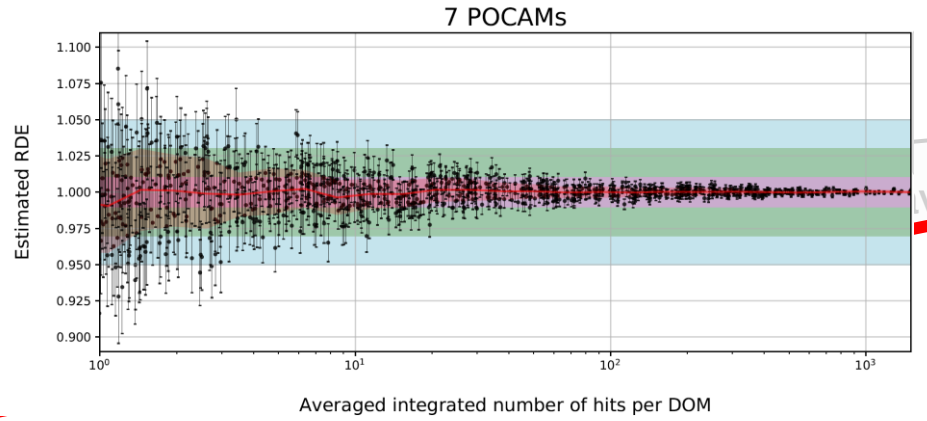


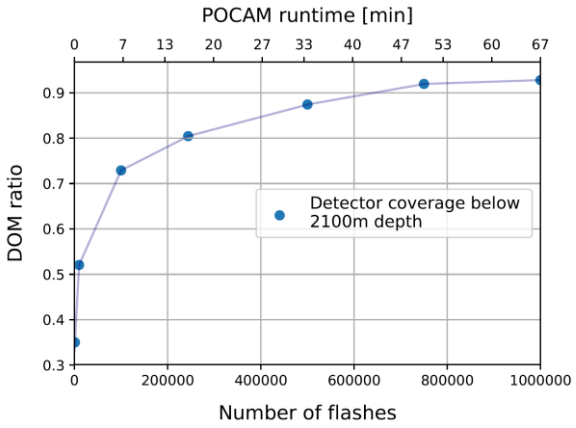


Photos: J. Thompson

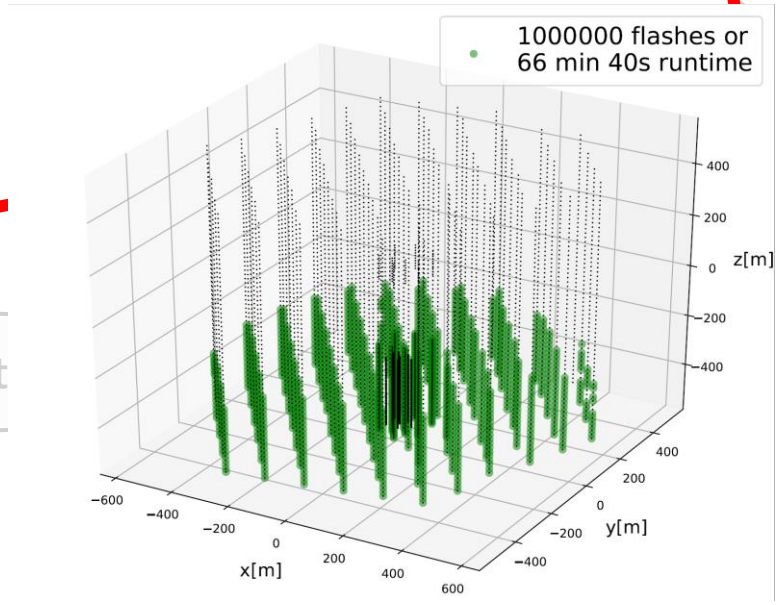
# POCAM stuff




Calibration Simulation

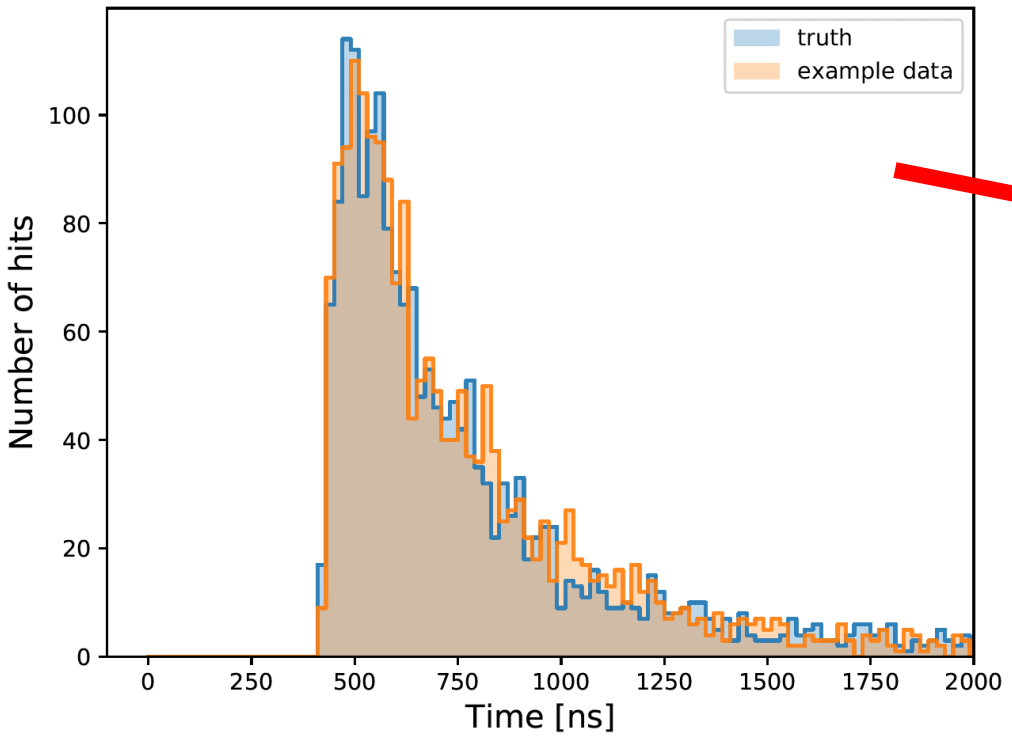


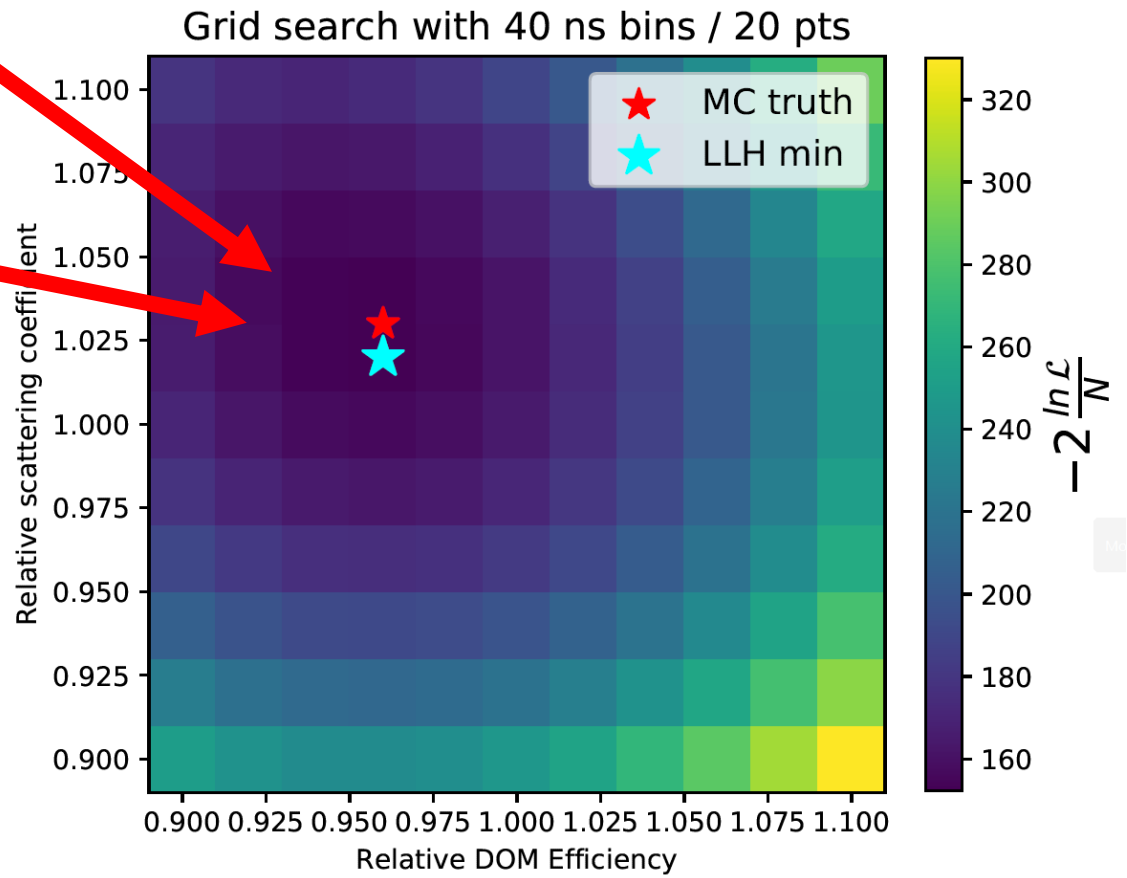
# Grid scan

$$\mathrm{LLH} = \sum_{\mathrm{POCAMs}_k} \sum_{\mathrm{DOMs}_j} \sum_{bins_i} \log p\left(d_{i,j,k} \mid t_{i,j,k}\right) \qquad p(d,t) = \begin{cases} \mathrm{Poisson}(d \mid t), t < 20 \\ \mathrm{Normal}(d \mid t), t \geq 20 \end{cases}$$

data

expectation

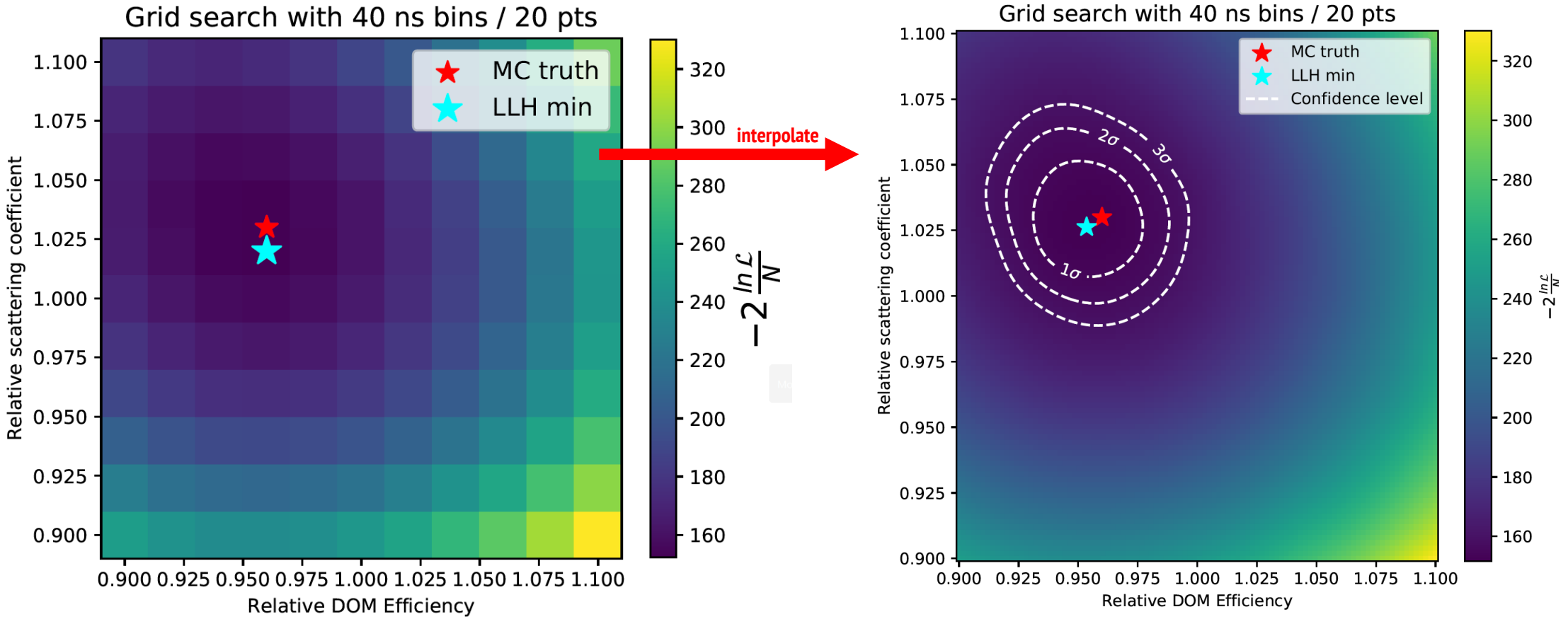


# Grid scan

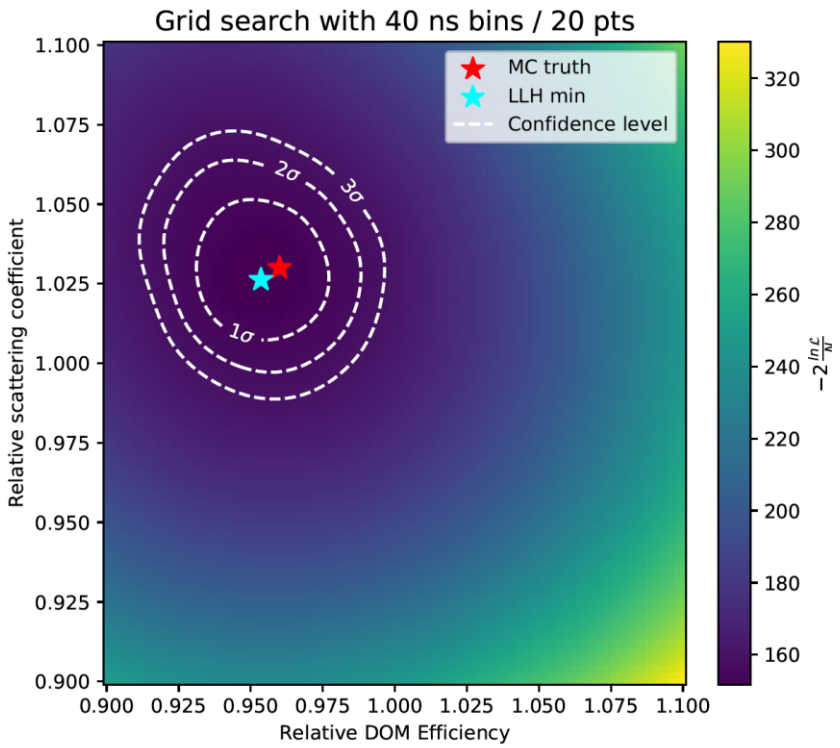
$$\mathrm{LLH} = \sum_{\mathrm{POCAMs}_k} \sum_{\mathrm{DOMs}_j} \sum_{bins_i} \log p\left(d_{i,j,k} \mid t_{i,j,k}\right) \qquad p(d,t) = \begin{cases} \mathrm{Poisson}(d \mid t), t < 20 \\ \mathrm{Normal}(d \mid t), t \geq 20 \end{cases}$$

data — expectation

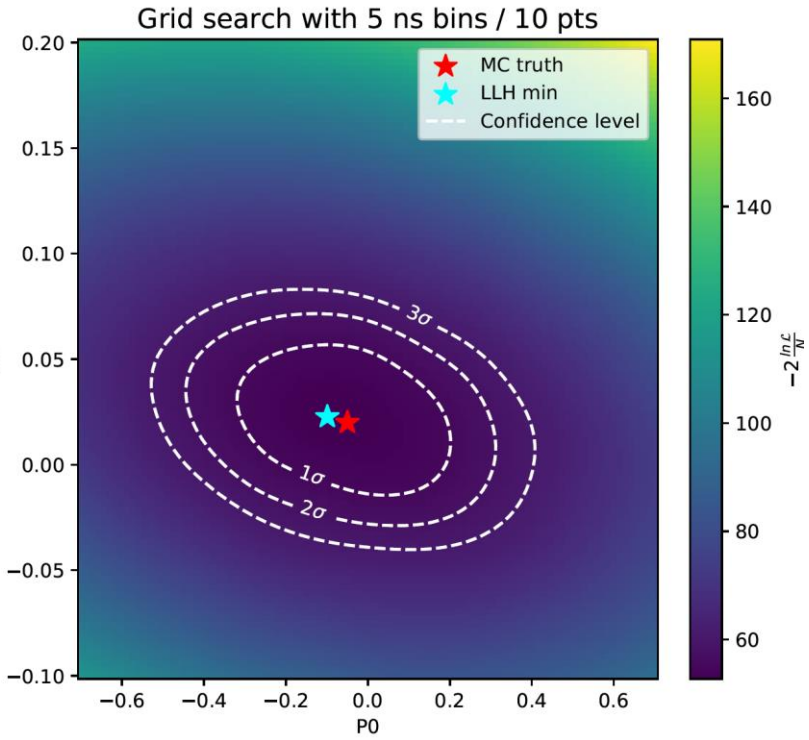


# Grid scan

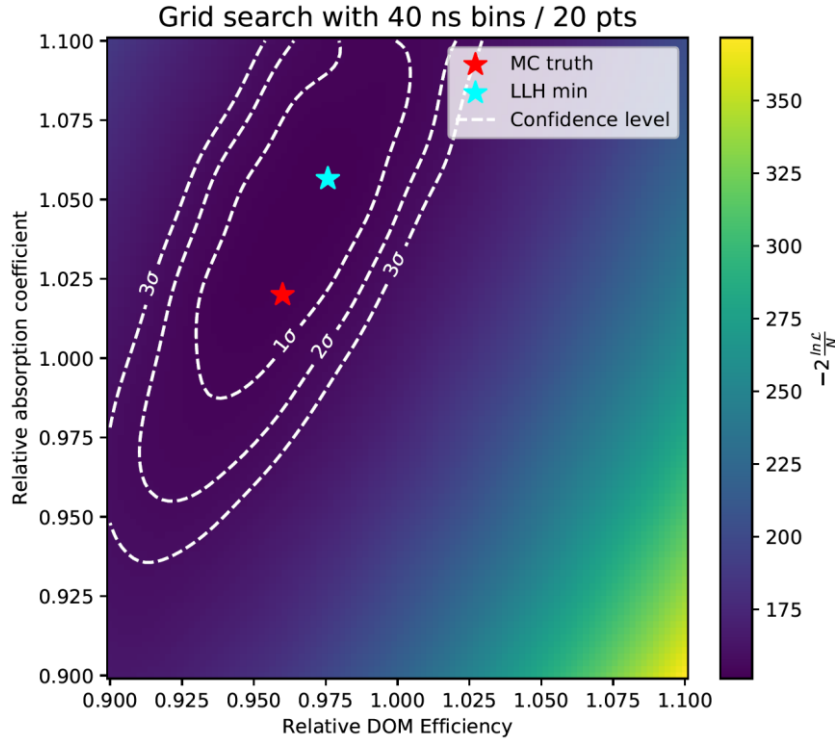
## DOM efficiency / Scattering




## P0 / P1



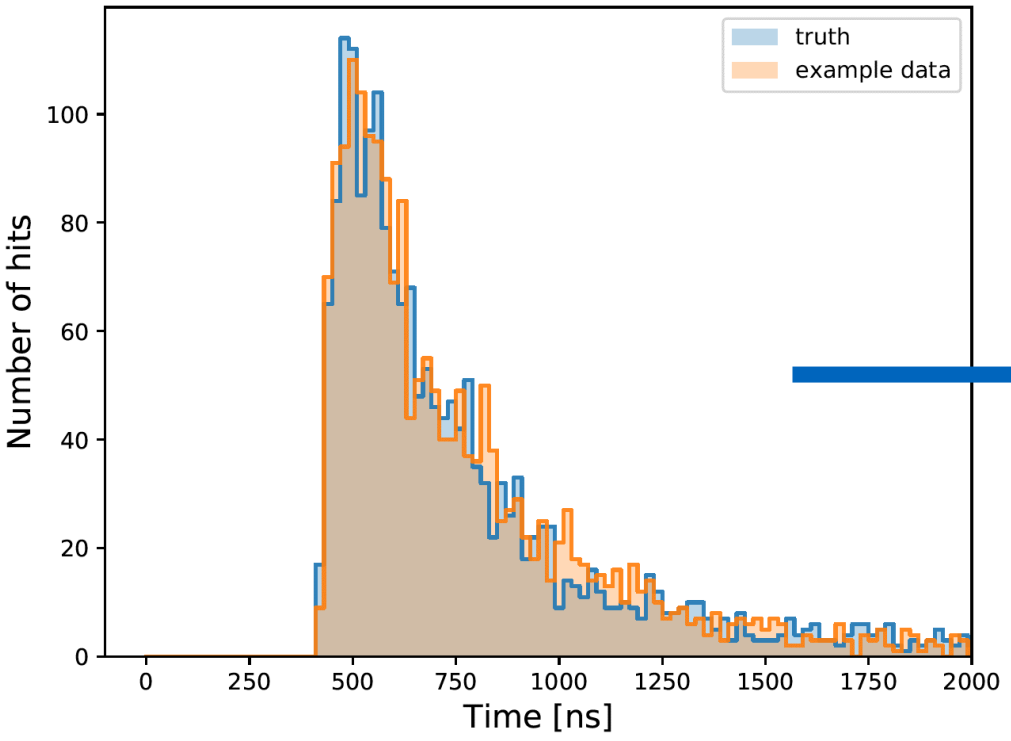

## DOM efficiency / Absorption



# Step 1 – Define (coarse) DOM response

Instead of using 1ns bins over the full event range of 5us, use only few but exponentially increasing bins
⟶ **gain statistics / bin** and **lose dimensionality**

5000 bins / DOM




30 smart bins / DOM