BERGISCHE UNIVERSITÄT WUPPERTAL

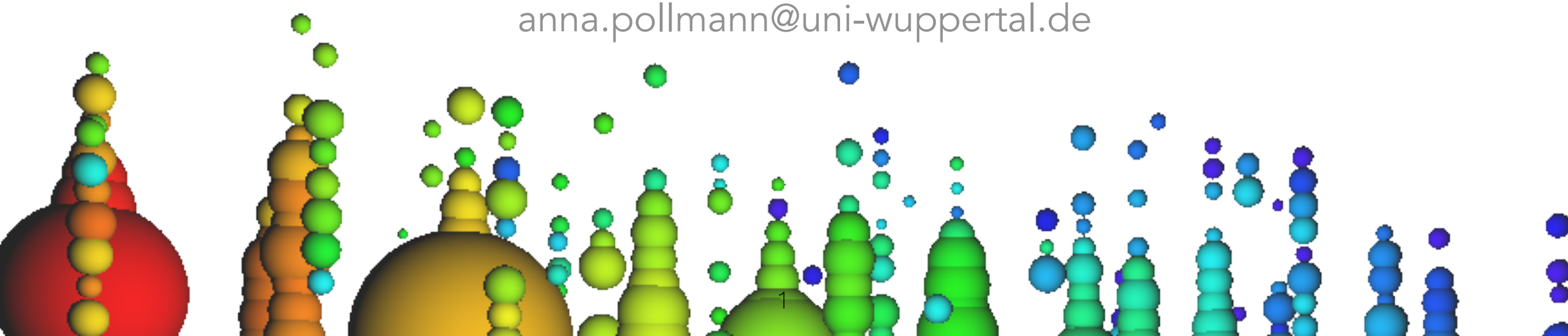
bmb+f - Förderschwerpunkt
Astroteilchenphysik
Großgeräte der physikalischen Grundlagenforschung

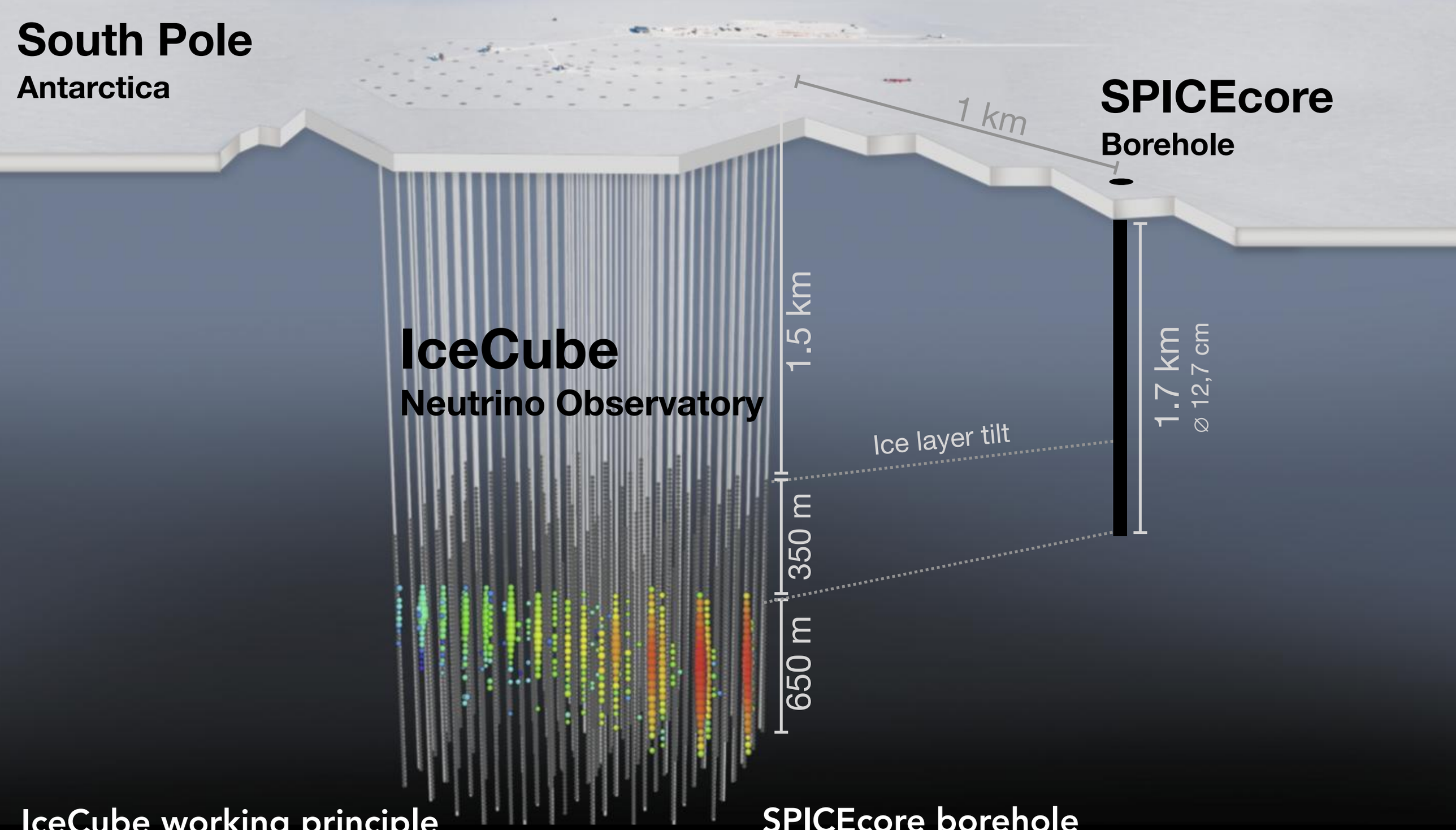
IceCube

# Enabling a New Detection Channel for BSM Physics with In-situ Measurements of Luminescence in Ice

Proceedings: POS 983

**Anna Pollmann**
anna.pollmann@uni-wuppertal.de





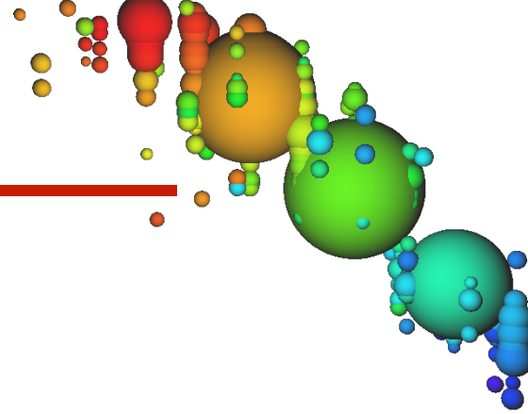

**IceCube working principle**

- particles interact with the deep clear ice
- emitted light is detected by sensors
- sensors optimized to record Cherenkov light

**SPICEcore borehole**

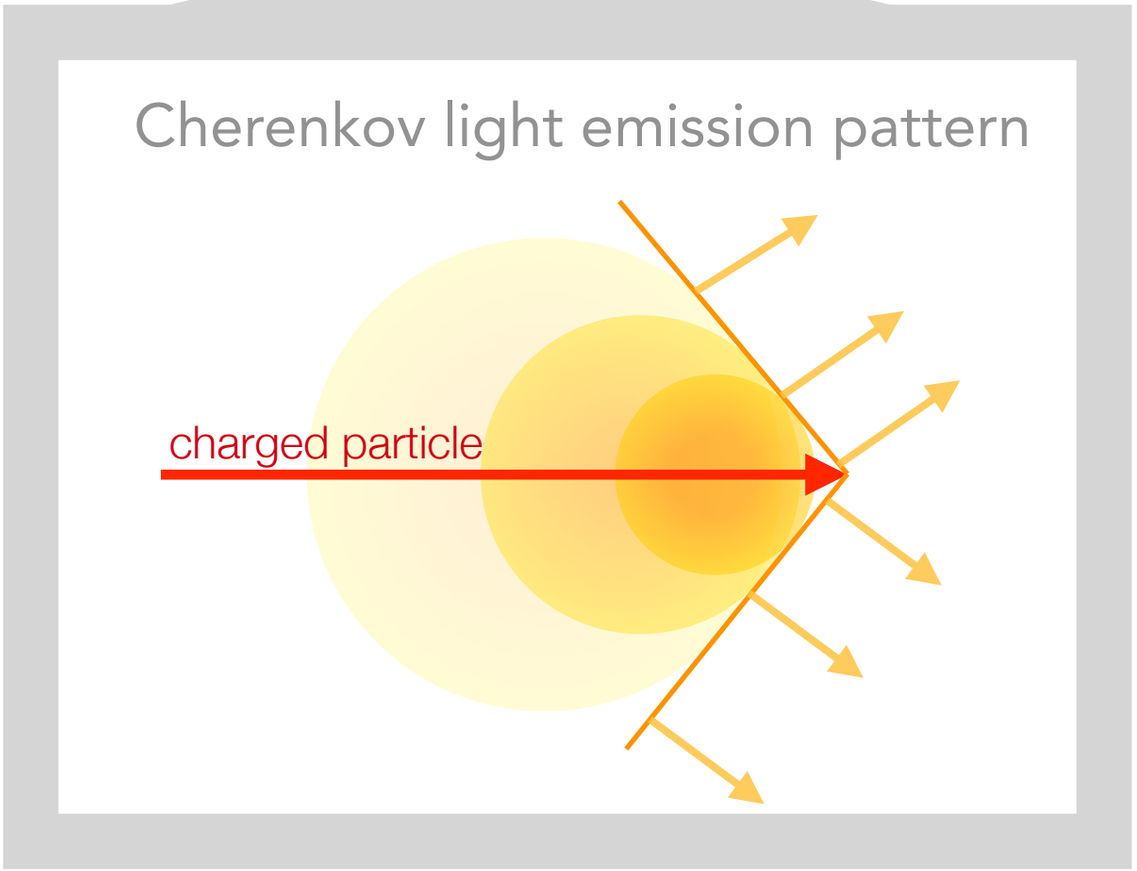
- filled with anti-freeze / drilling grease
- measurements in 2018:
  - UV transparency (POS 847)
  - scattering / absorption (POS 926)
  - this work

# Light production by (exotic) particles in ice



Relativistic speeds

- continuous light emission
  - Cherenkov light
  - Cherenkov light from secondaries
- stochastic losses
  - bremsstrahlung
  - pair production
  - photonuclear interactions



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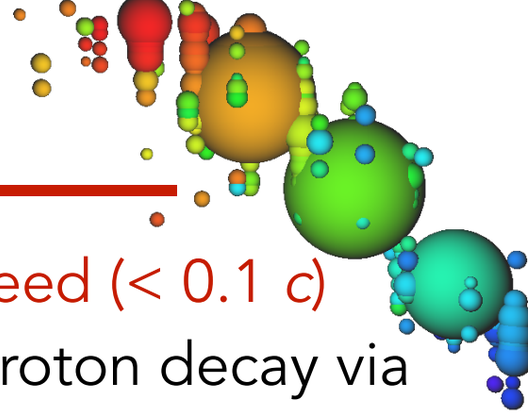

Relativistic speeds

- continuous light emission
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- stochastic losses
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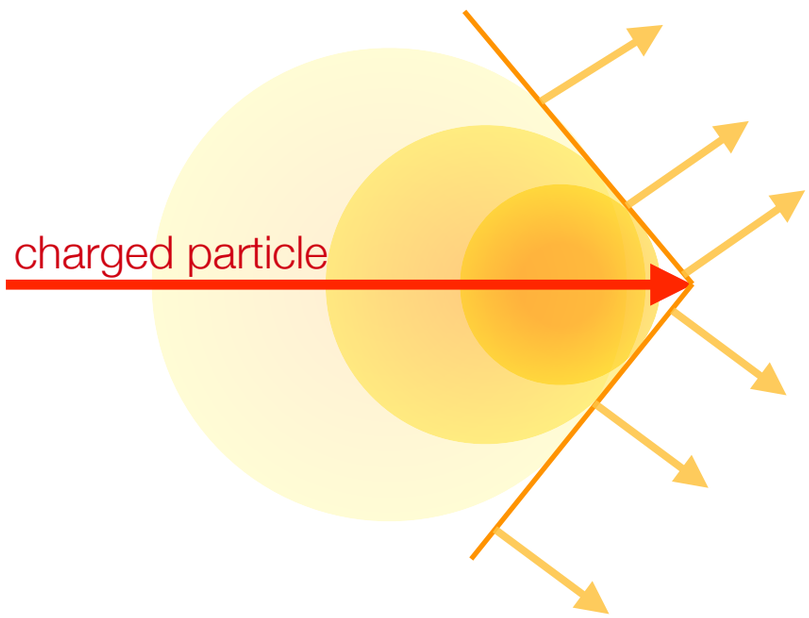
  - pair production
  - photonuclear interactions

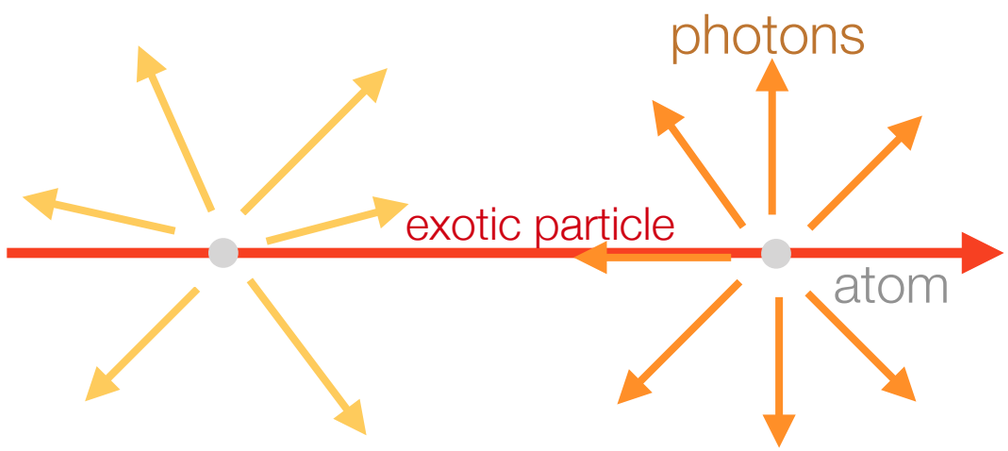
Slow particle speed (< 0.1 *c*)

- catalysis of proton decay via Rubakov-Callan
  (predicted theoretically in some models)
- thermal shock waves
  (not used yet)

Cherenkov light emission pattern




Light emission from proton decay

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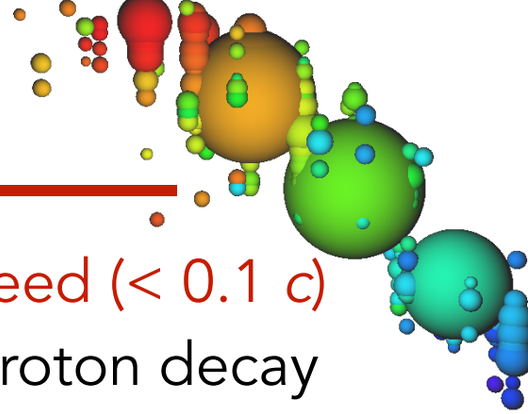

Relativistic speeds
- continuous light emission
- stochastic losses

Intermediate speed (0.1-0.5 *c*)

➡ **not covered yet**

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- catalysis of proton decay
- thermal shock waves

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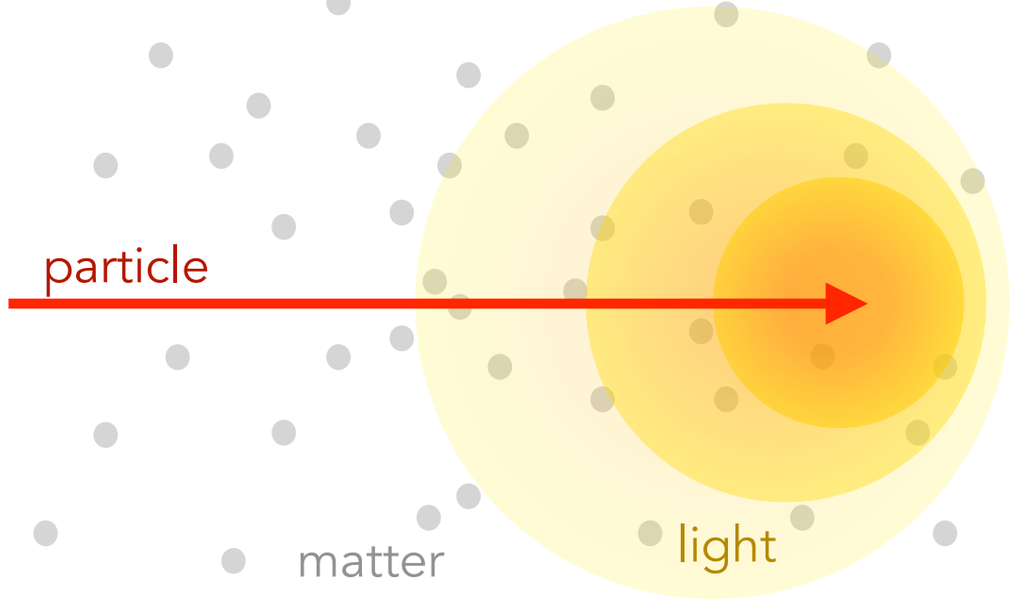
## Idea: Luminescence light

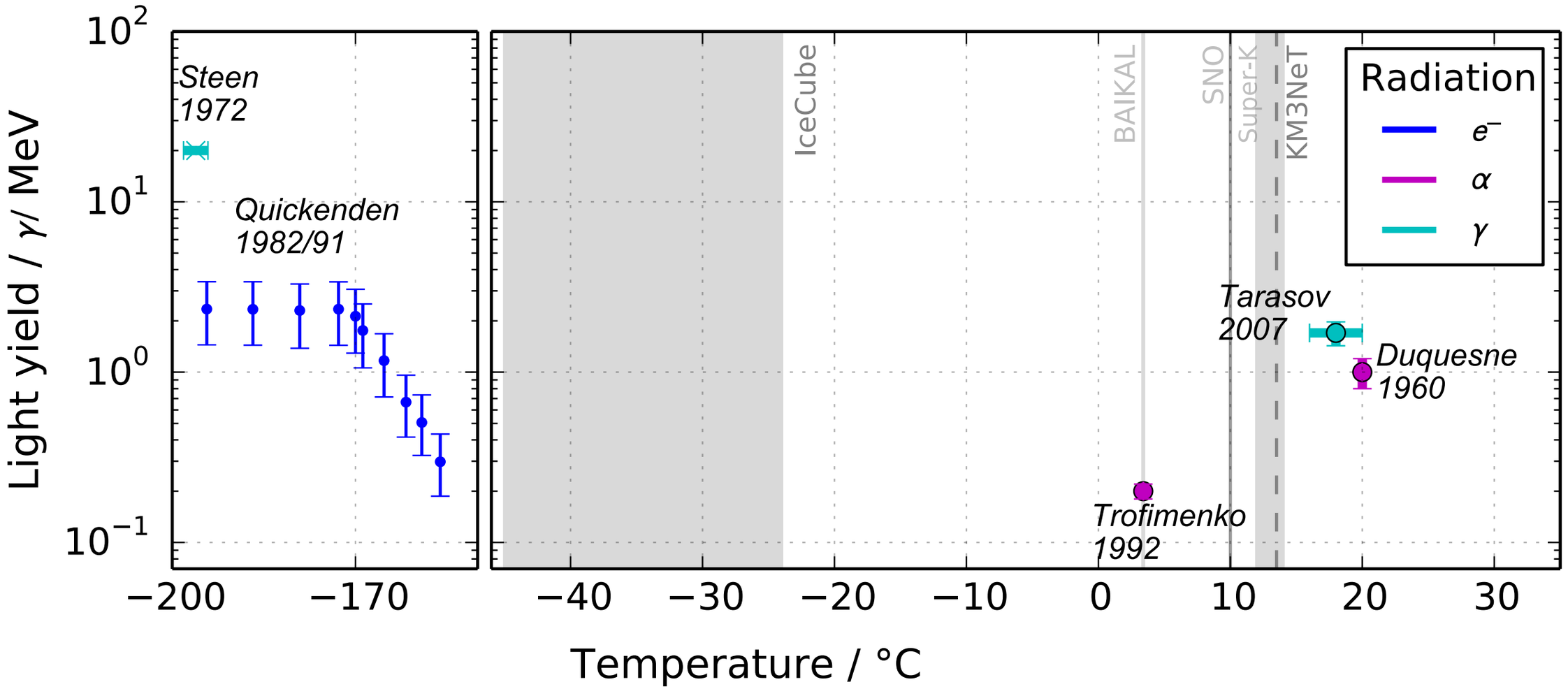
- ionising radiation passes through matter
- it excites atoms/molecules
- relaxation with light emission

- works for all speeds
- works for all ionising particles

Light yield defines detectability!



# Previous light yield measurements




- ice quality varies significantly between measurements
- different radiation causes different amount of quenching

- uncertainties of laboratory measurement originates from ice quality
- Trofimenko and Wuppertal are the only in-situ measurements, all others use cleaned water

***arxiv:1710.01197***

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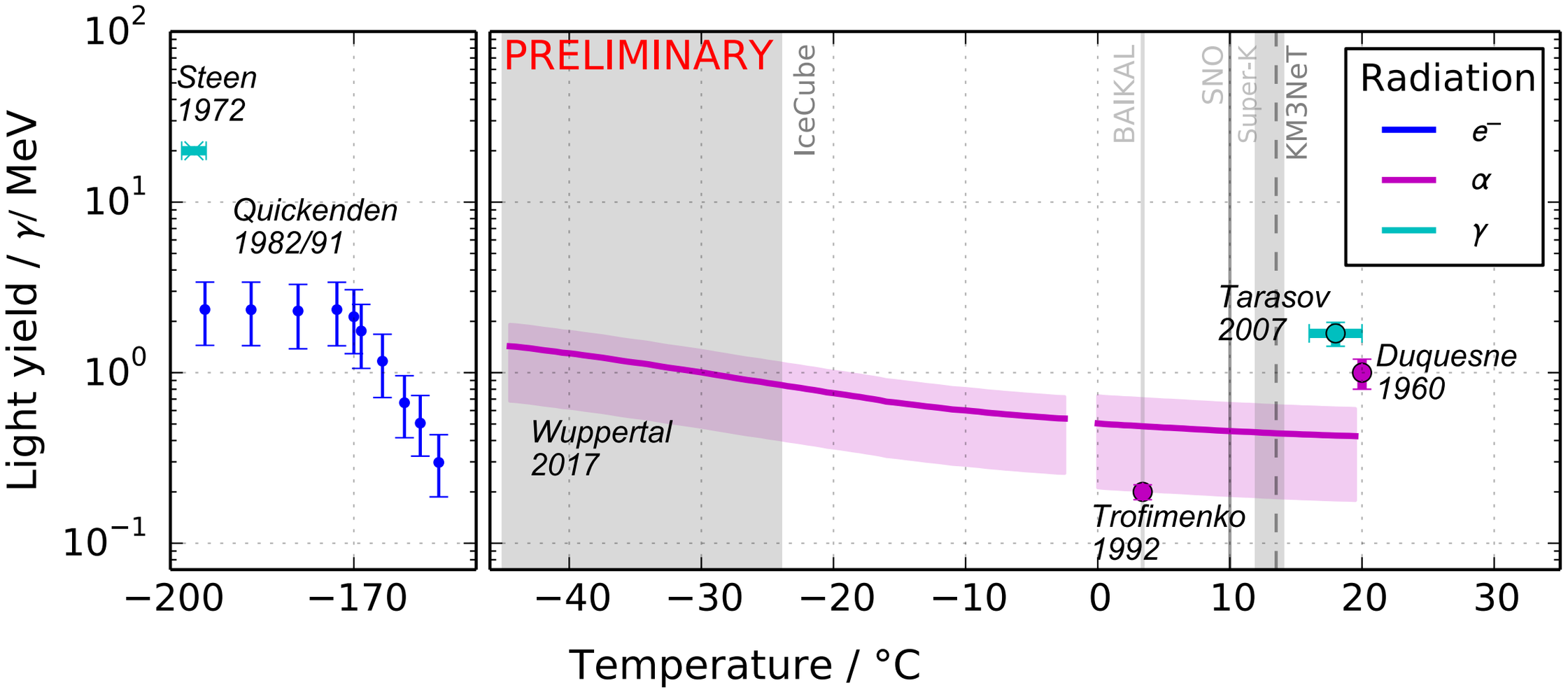


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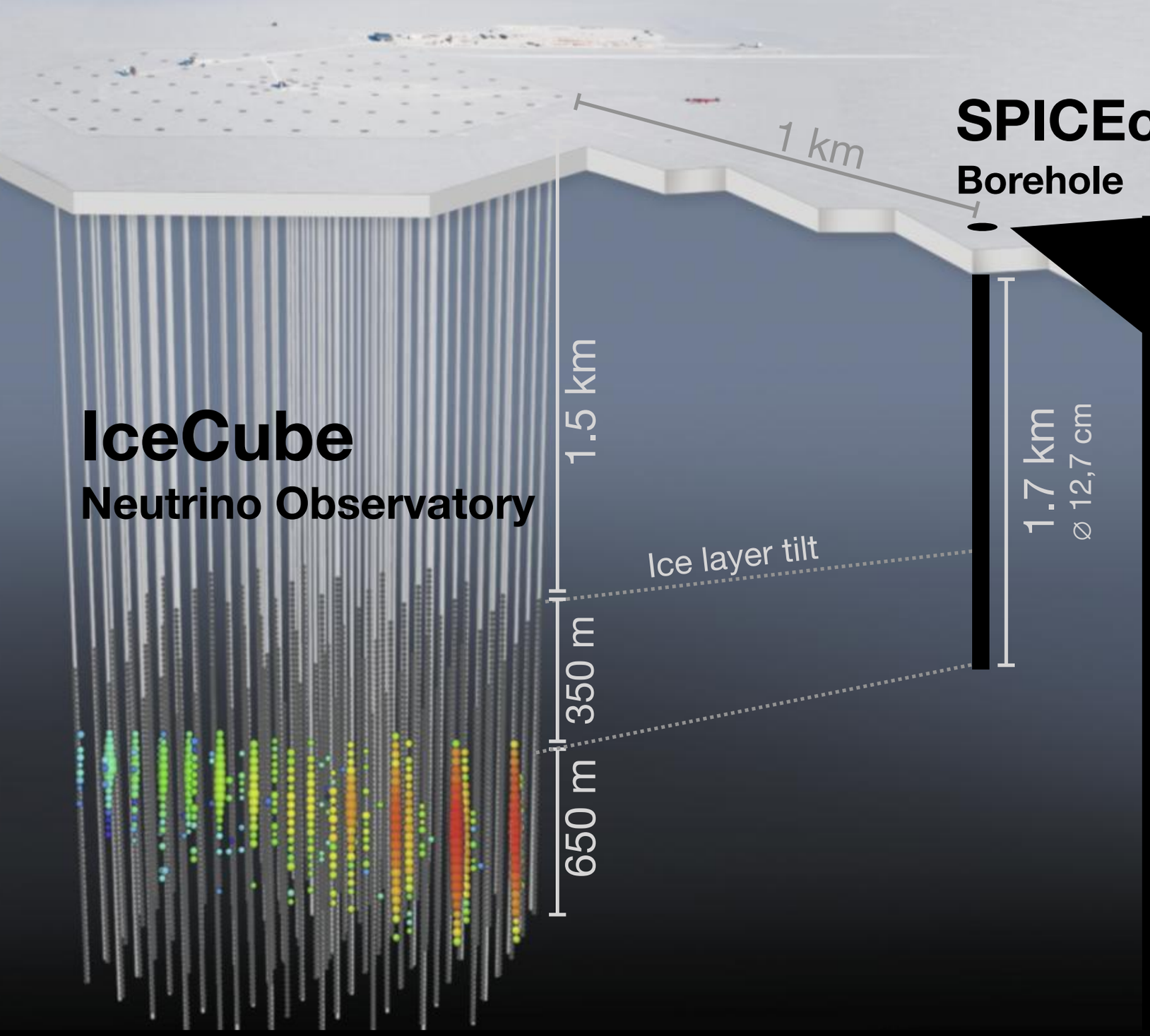
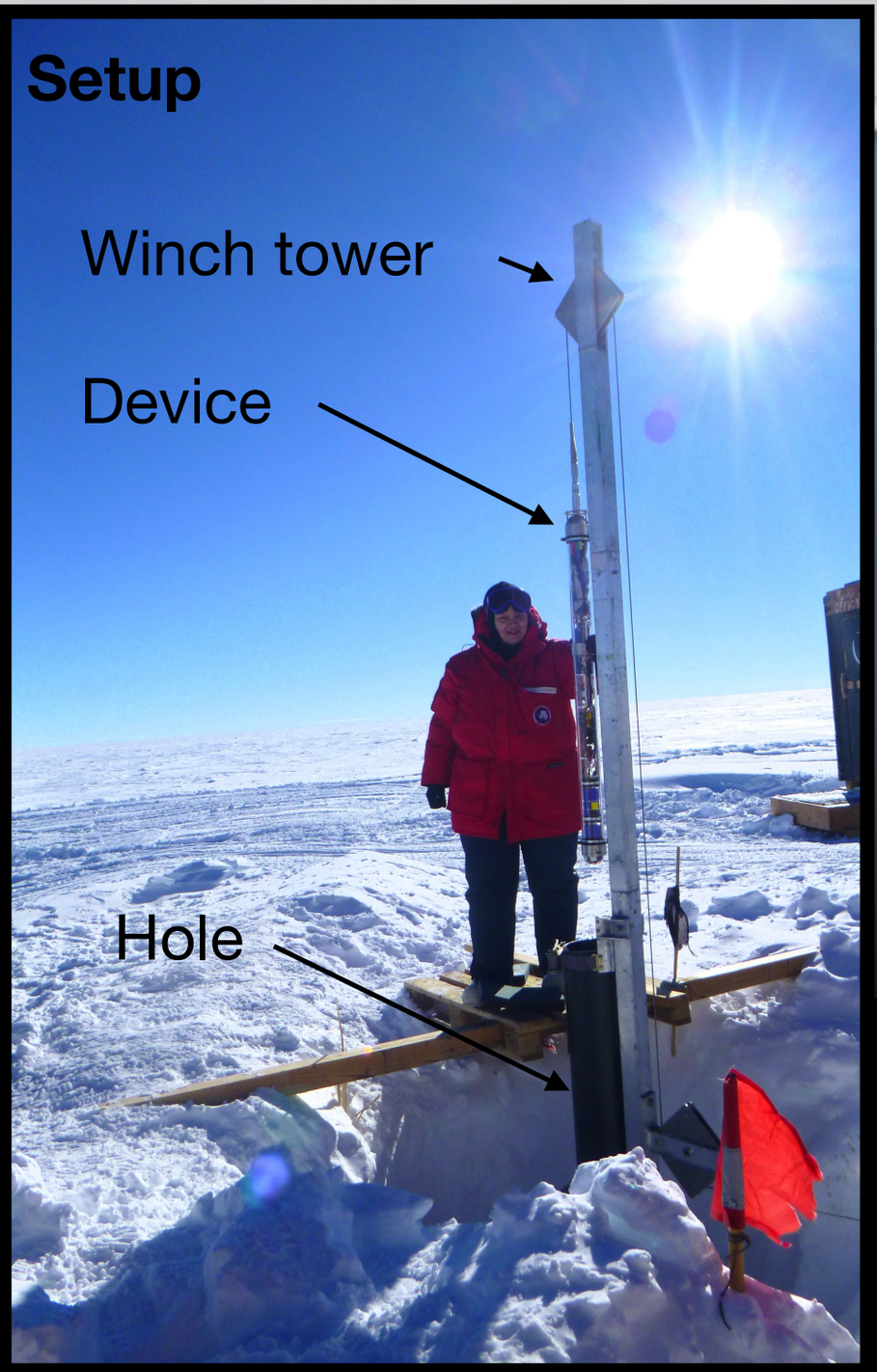



Other measurements in SPICEcore:

- UV transparency (POS 847) Jannes Brostean-Kaiser
- scattering / absorption (POS 926) Christoph Tönnis

# Luminescence Logger

**Goal**

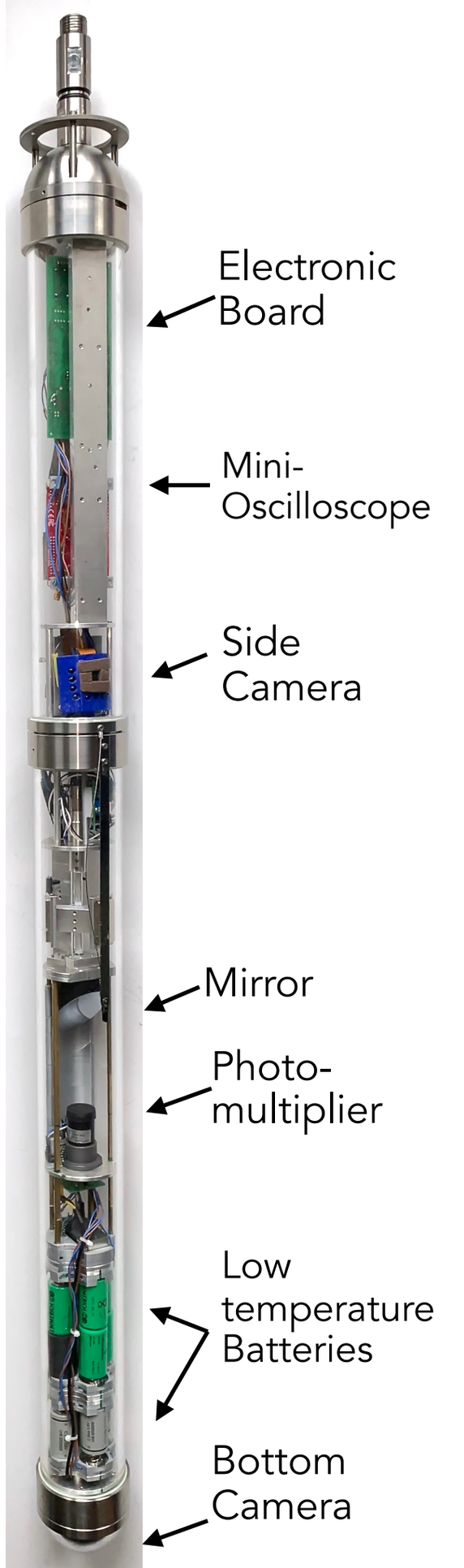
- irradiate ice with β-source and measure back-scattered light

**Method**

- press source against ice
- guide scattered light onto photomultiplier

**Details**

- diameter: max 92 mm
- length: 1.30 m
- commercial mini USB-oscilloscope for readout
- light detection with photomultiplier tube
- several sensors: i.e. temperature, gyro, IR camera



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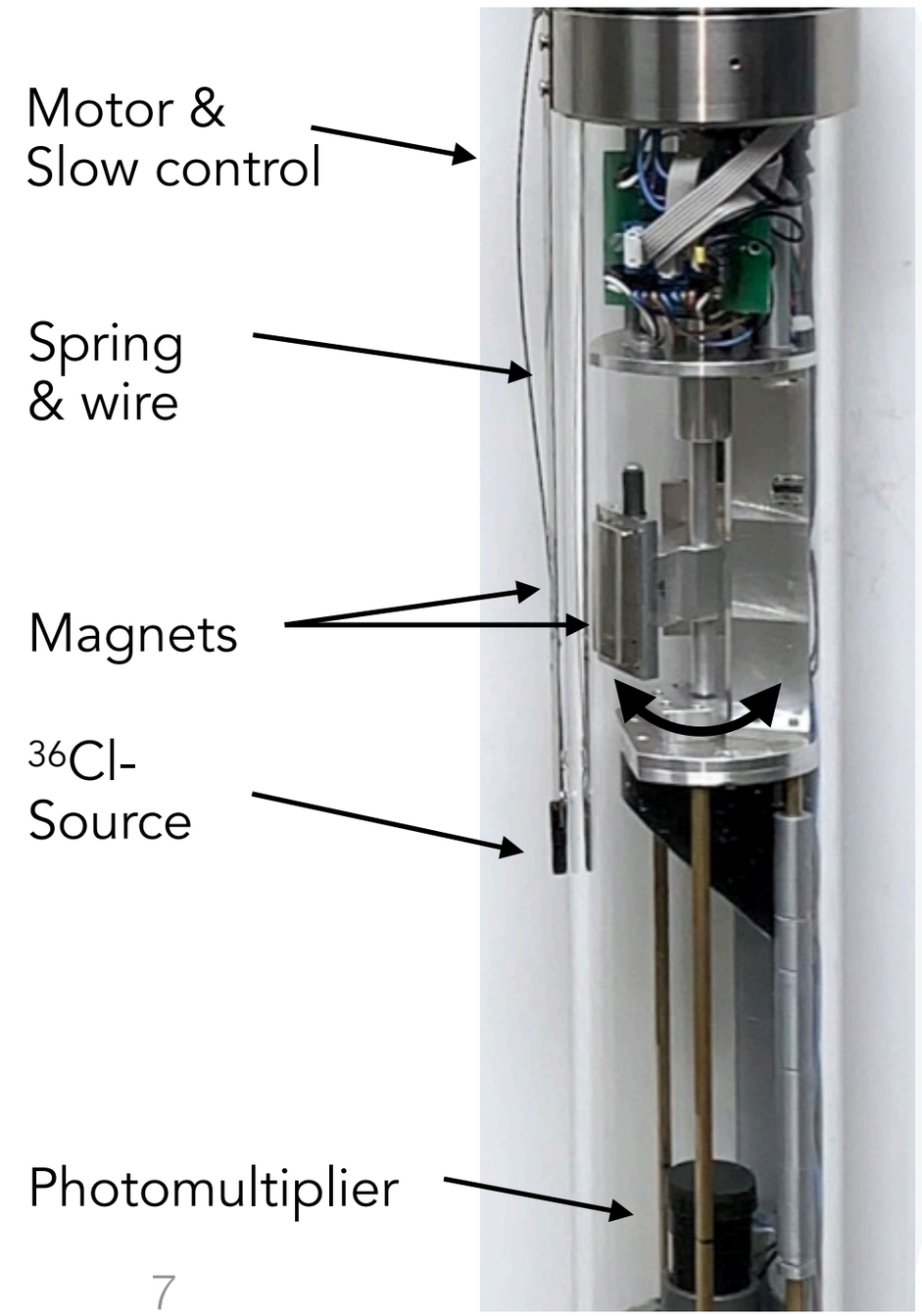
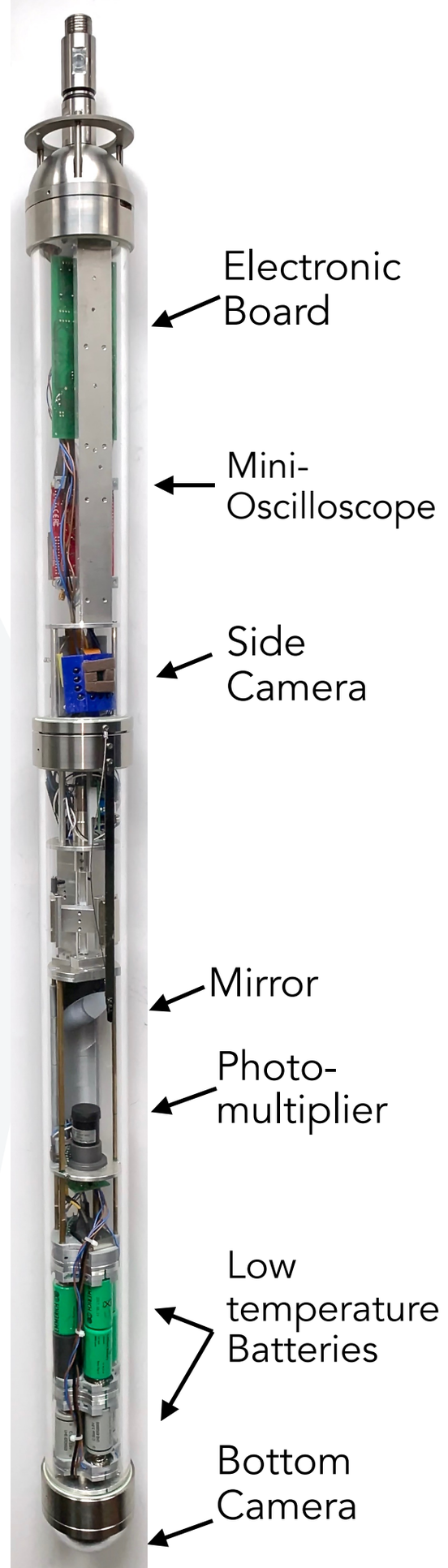
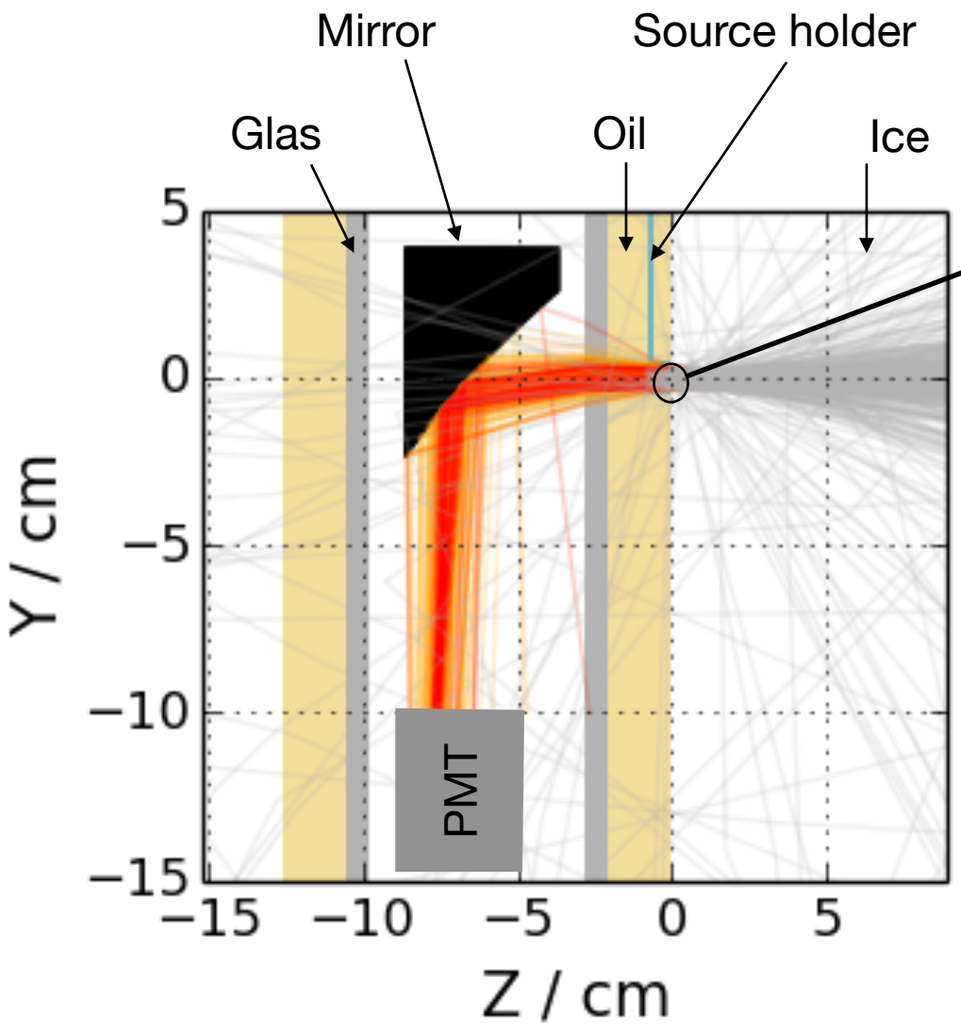


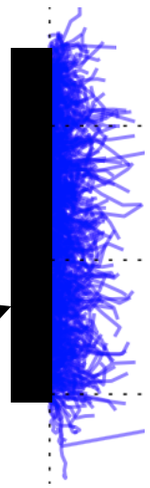
# Light yield analysis

- GEANT4 simulation of source and electrons in Estisol & Ice (tracks & energy losses)




Custom ray tracing highlighting Cherenkov (orange) and Luminescence (red) photons reaching PMT plane

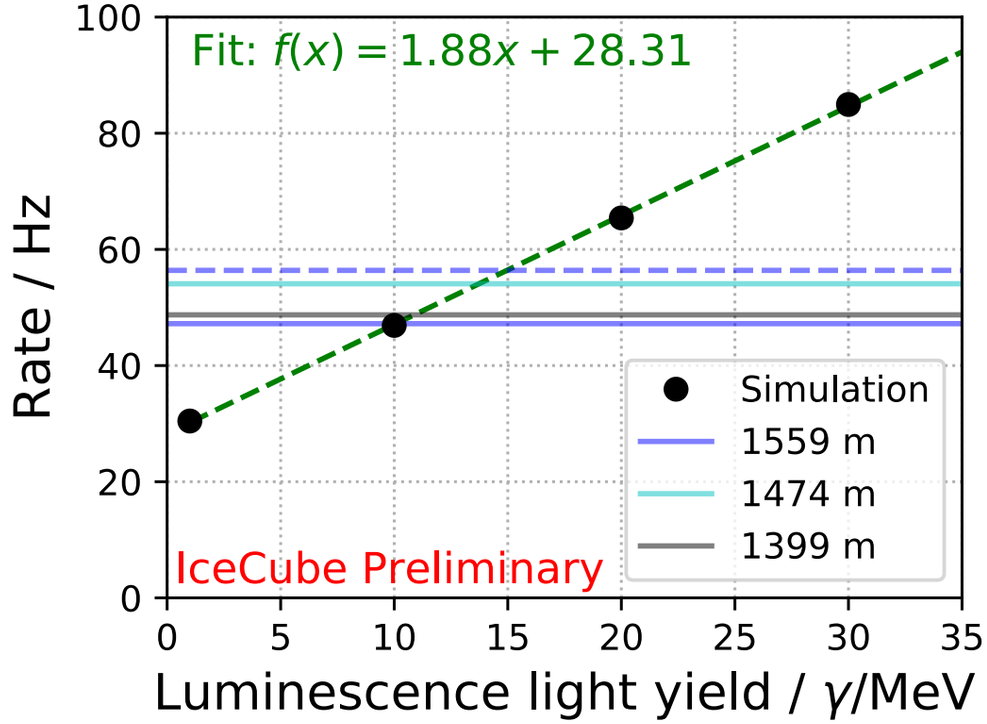
Electrons leaving source into Ice (GEANT)

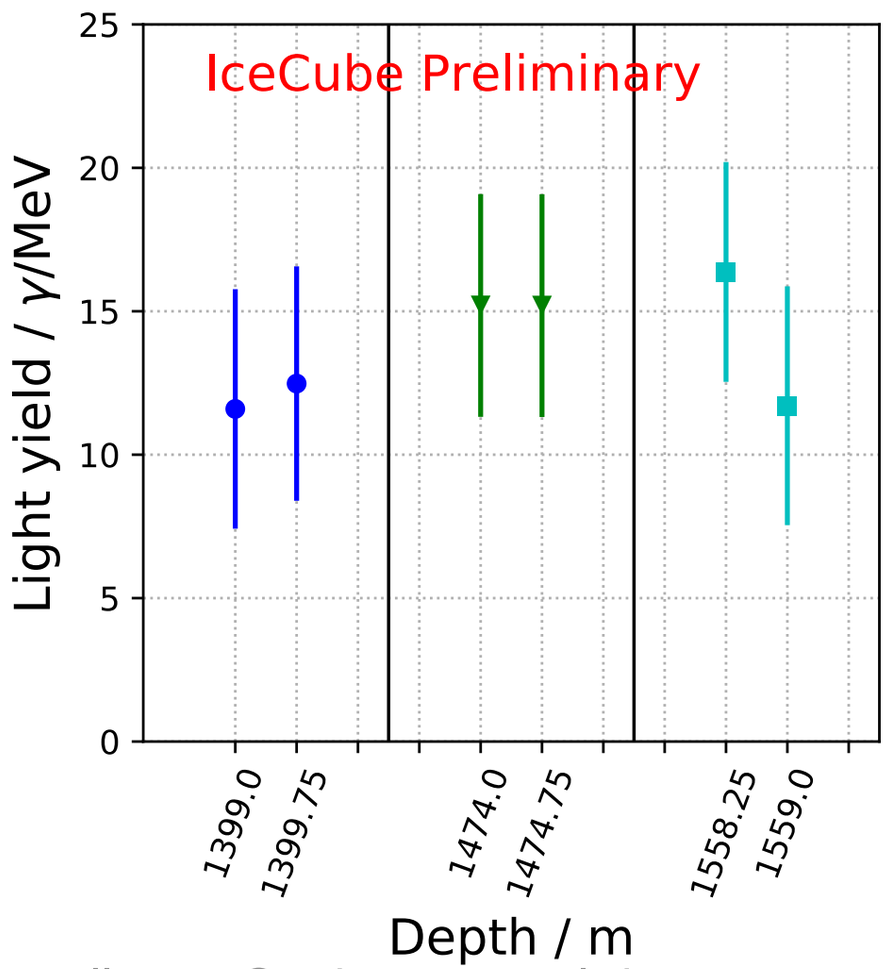


- custom ray tracing of photons separating the 4 contributions of
  - Cherenkov and Luminescence in Estisol
  - Cherenkov and Luminescence in ice

# Light yield analysis

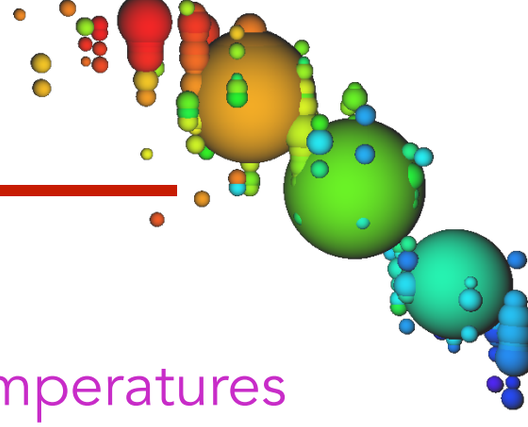
- varied the distance of source to the ice
- varied light yield of ice luminescence
- fit resulting photon detection efficiency and compared with measured rates to obtain light yield bounds
  - Estisol luminescence
  - unknown average distance of source to ice




- uncertainties included (a.o.)
  - scattering (impact: +/- 13%)
  - absorption (impact: +/- 13%)
  - source activity (impact: -19% +11%)
  - estisol luminescence yield (impact: +/- 15%)

# Luminescence light measurement



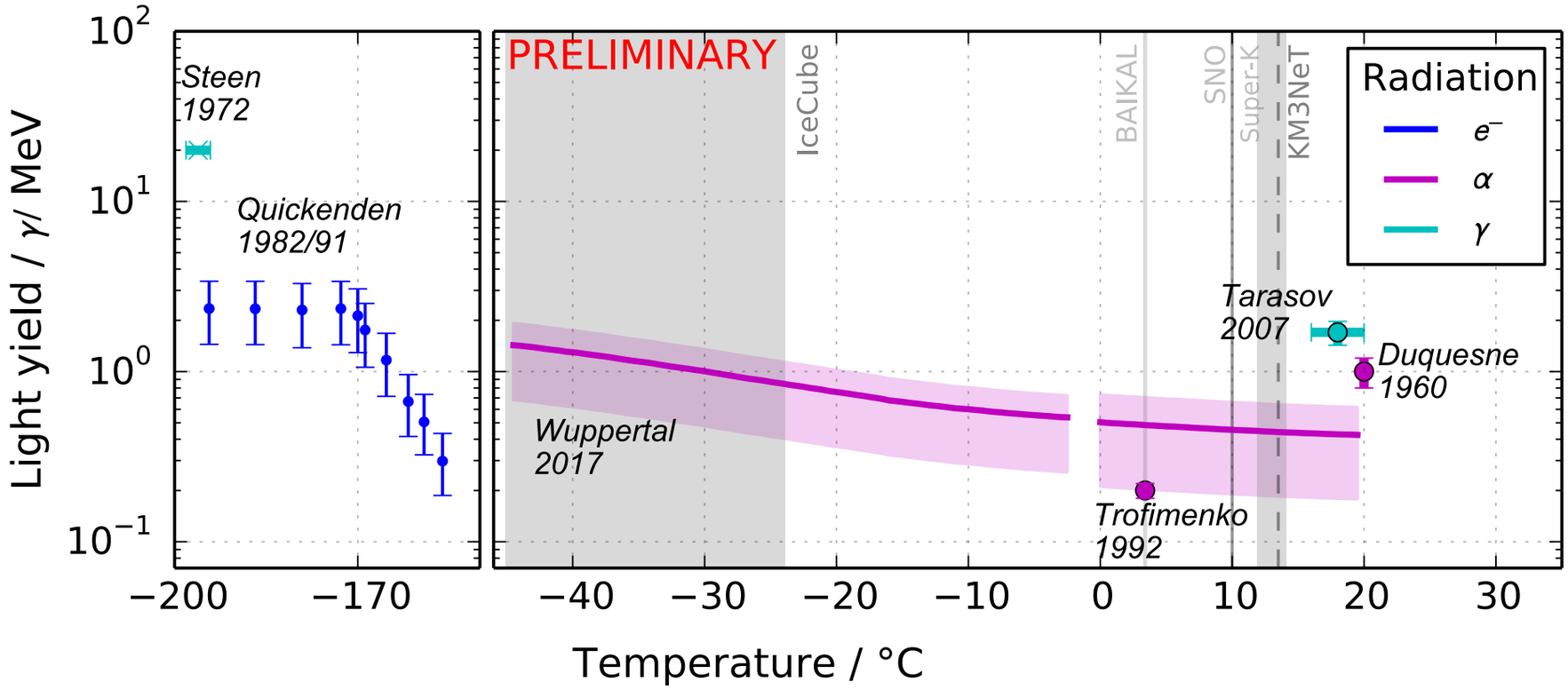
**Characterisation** via

- light yield
- decay kinetics
- emission spectrum
- quenching

First laboratory measurement at temperatures of neutrino telescopes

**Dependencies**

- temperature
- impurities / solubles
- radiation type
- pressure




**Applications**

- energy calibration of high energy neutrino events (astrophysical neutrinos)
- detection of slowly moving particles
- modelling of correlated noise on long time scales

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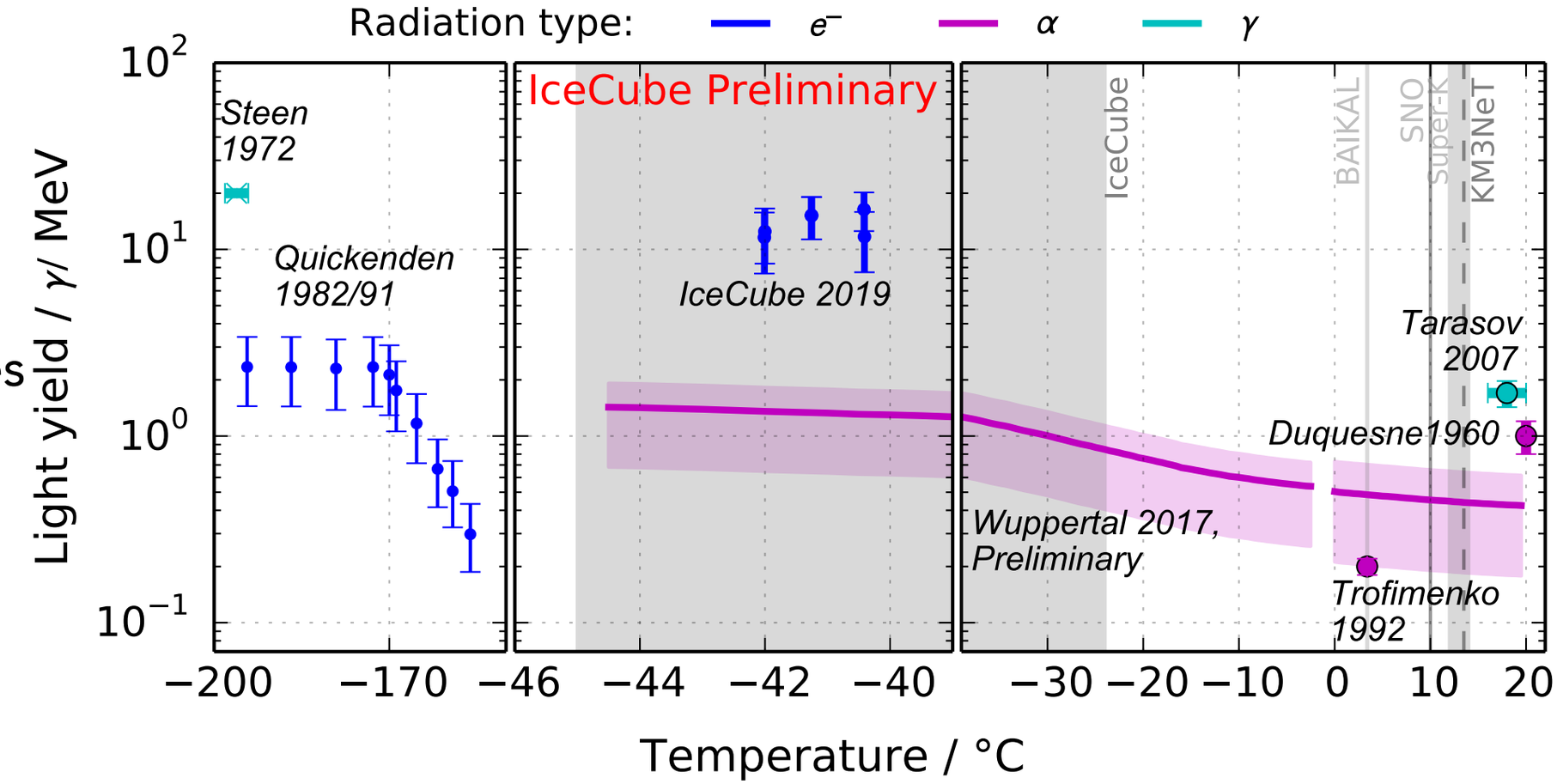
First laboratory measurement at temperatures of neutrino telescopes & first in-situ measurement




**Applications**

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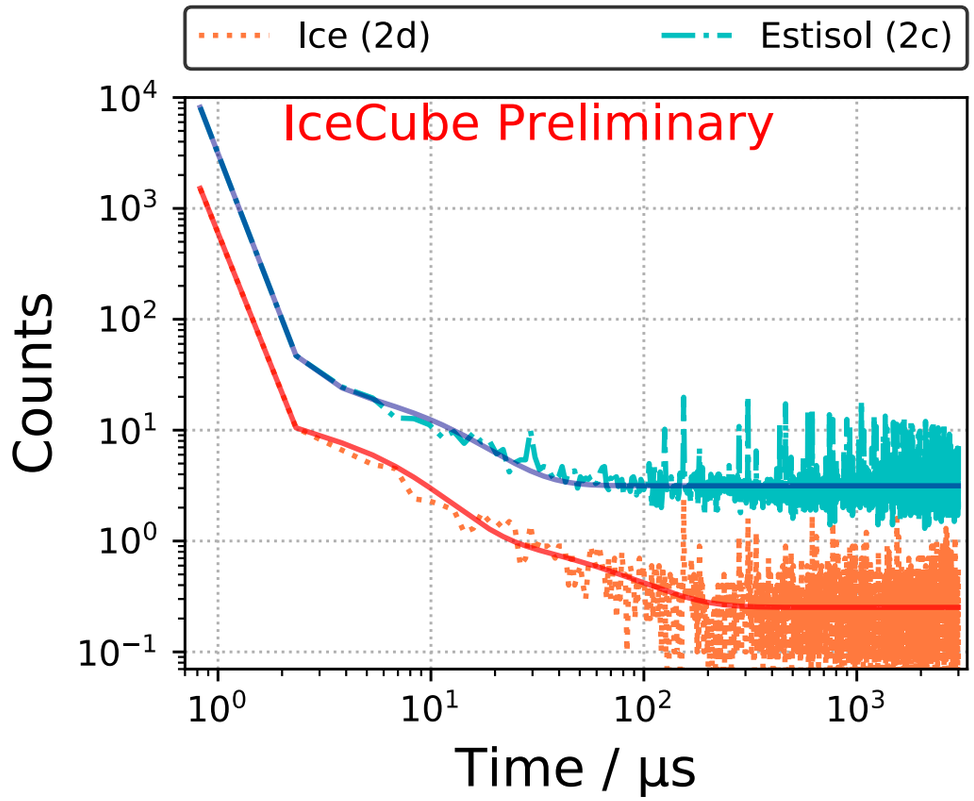
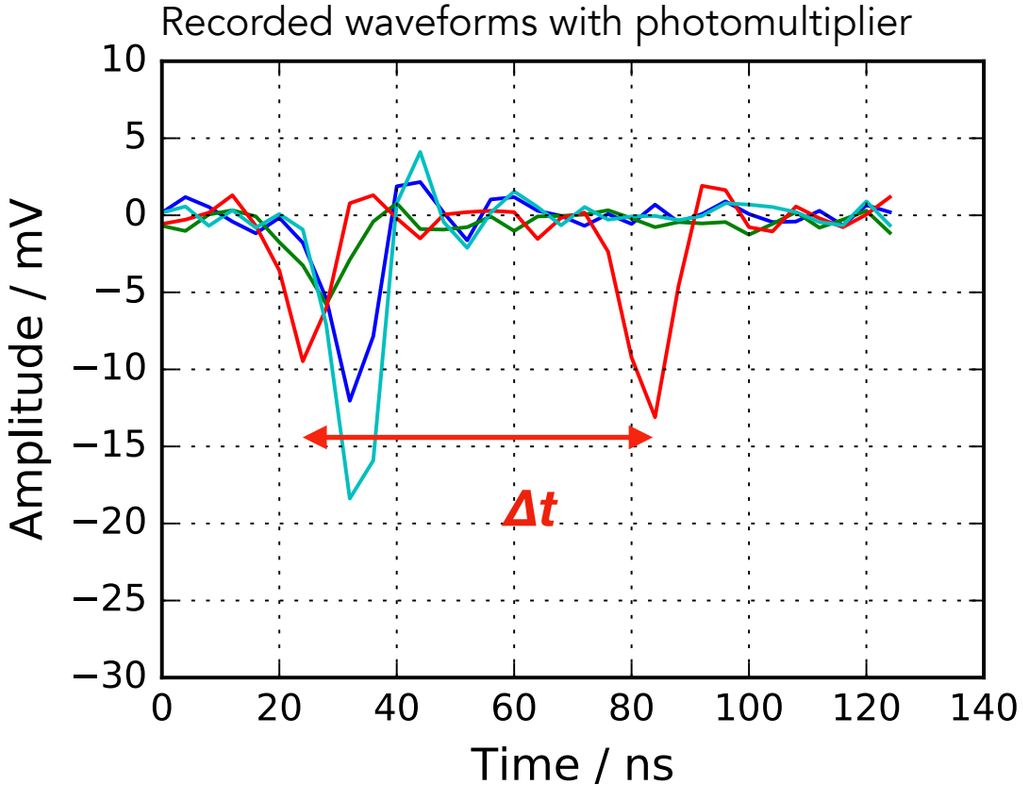
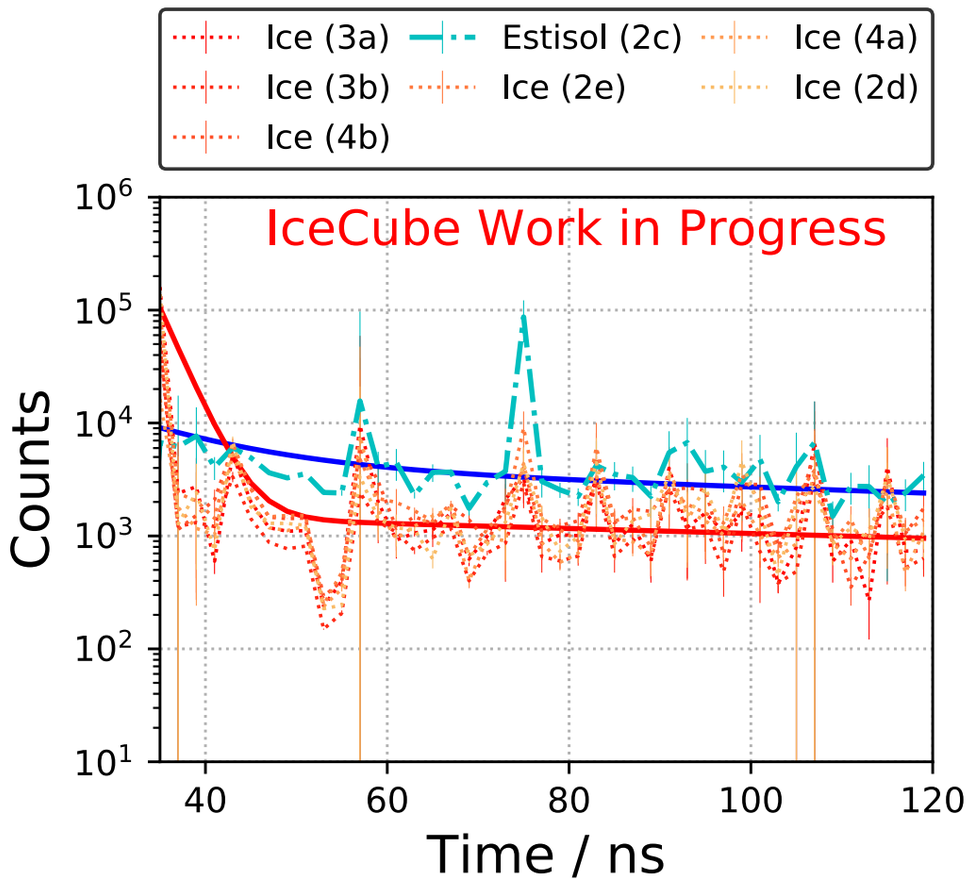
# Time differences

- time differences between a pulse and all following pulses
- 40-120ns:
  - obtained from waveform
  - corrected for PMT effects
- > 120ns: obtained from trigger timestamps

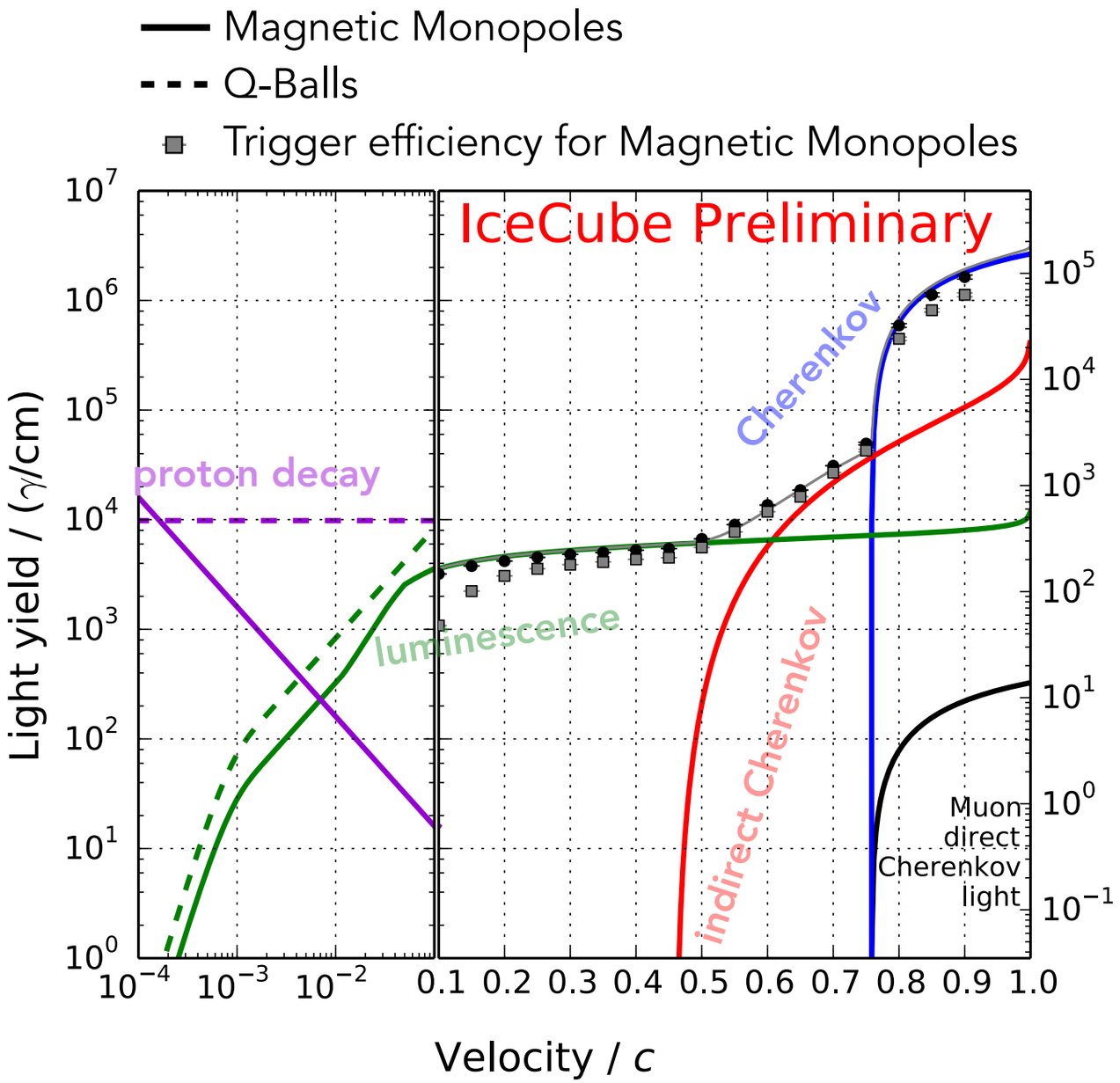


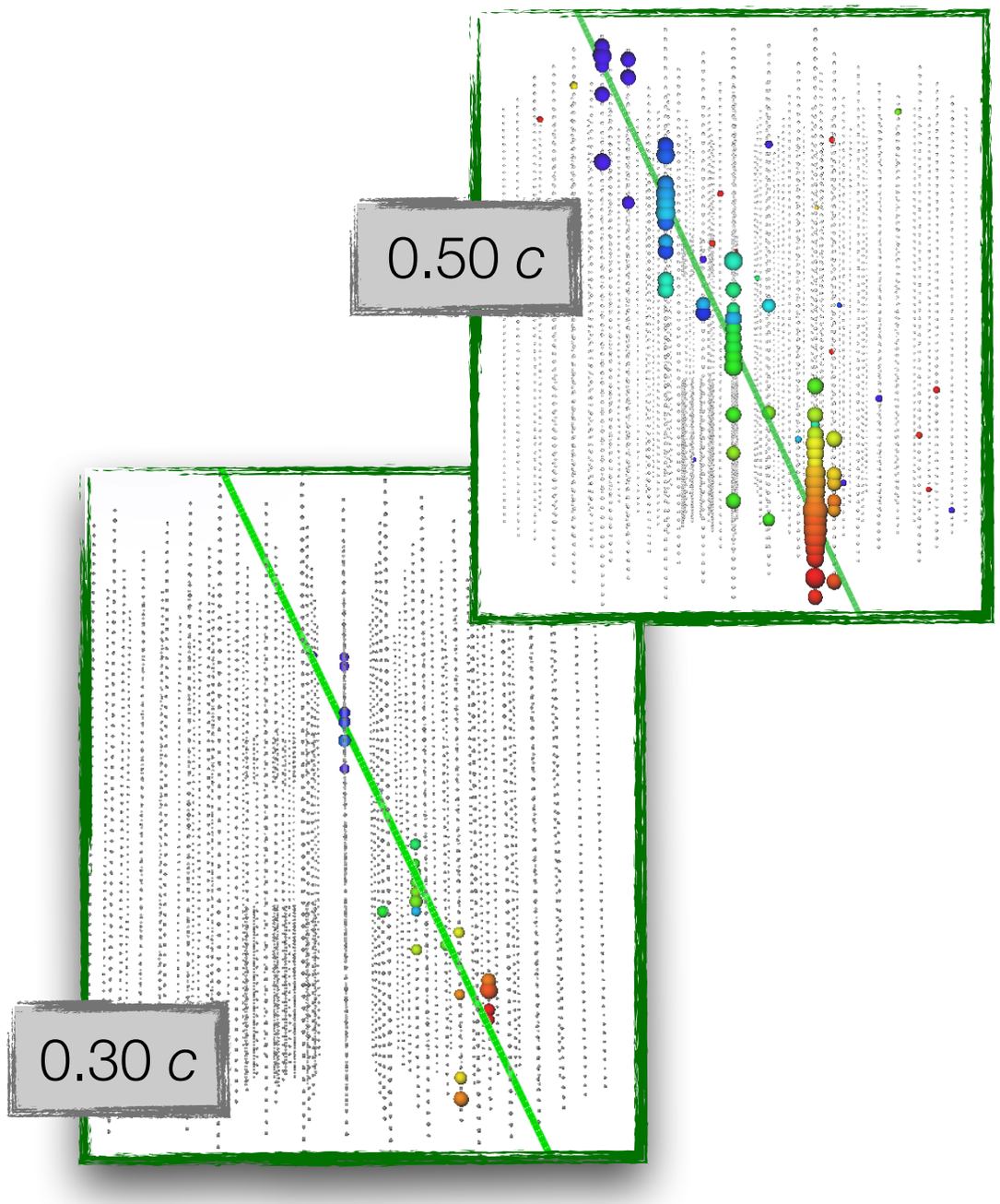
# Luminescence to detect exotic particles

## Light yield




*Work by Frederik Lauber and Sarah Pieper, Wuppertal*

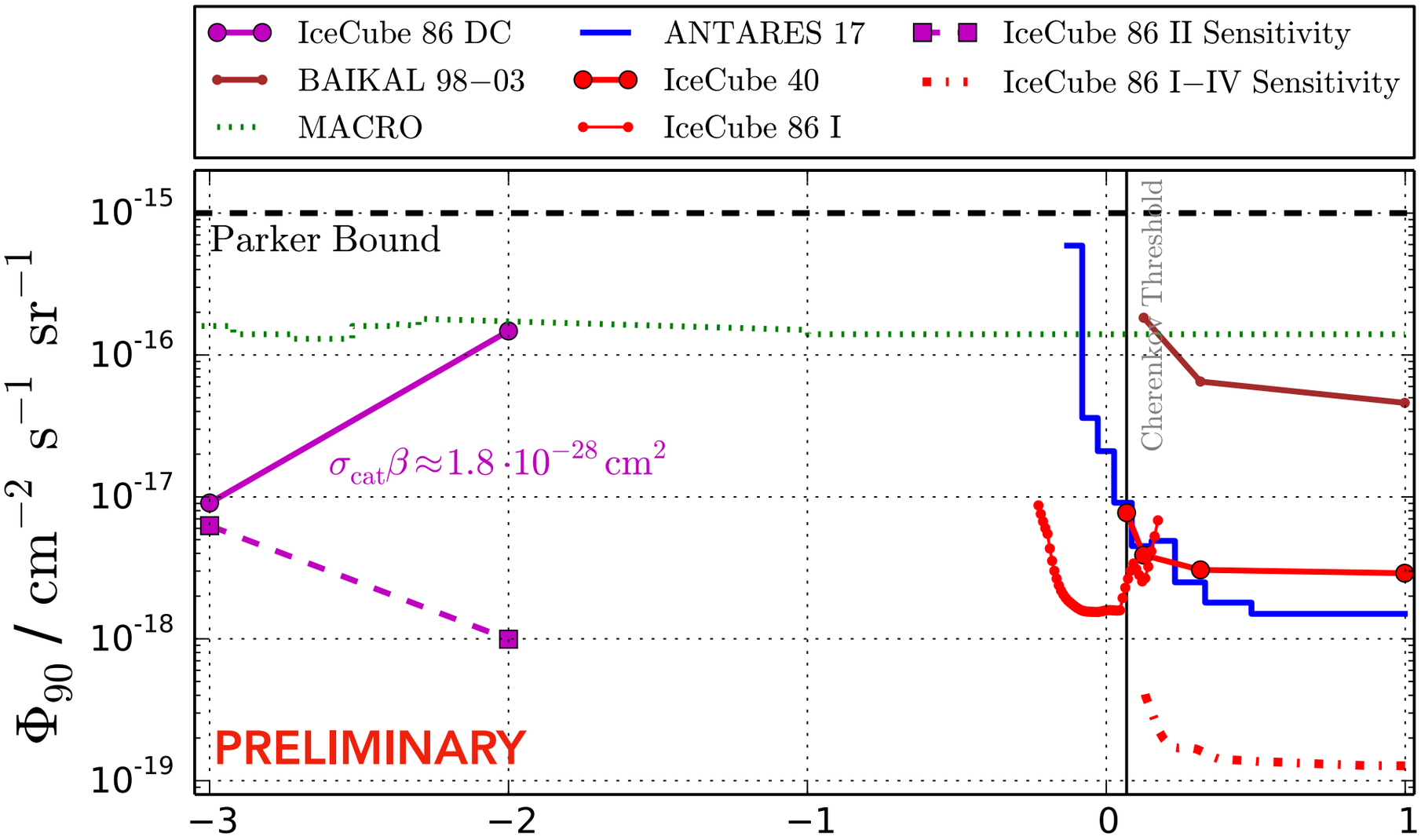
## Simulation of Magnetic Monopoles




**Color ≙ time** (red -> blue)

**Size ≙ light amount**

# Mapping the parameter space of magnetic monopoles




**Catalysis of proton decay**

**Luminescence**

*New sensitivity by Frederik Lauber, Wuppertal*

**Indirect Cherenkov radiation**

**Direct Cherenkov radiation**

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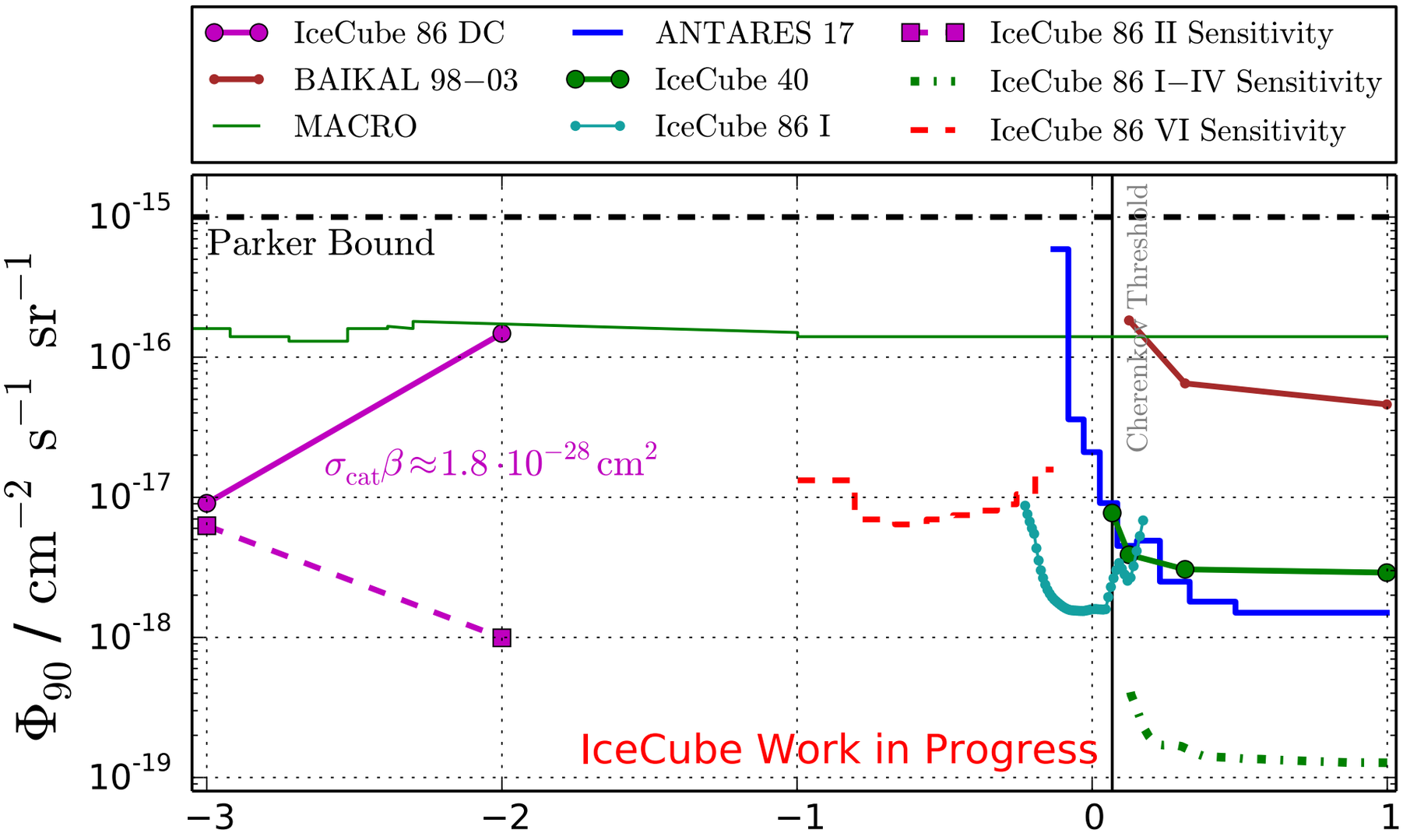


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# Summary

- first measurement of luminescence in ice executed in-situ
- first analyses ongoing using luminescence light as detection channel
- sensitivity for magnetic monopoles exceeds previous limits by far

More information in proceedings: **POS 983**

Other measurements in SPICEcore:

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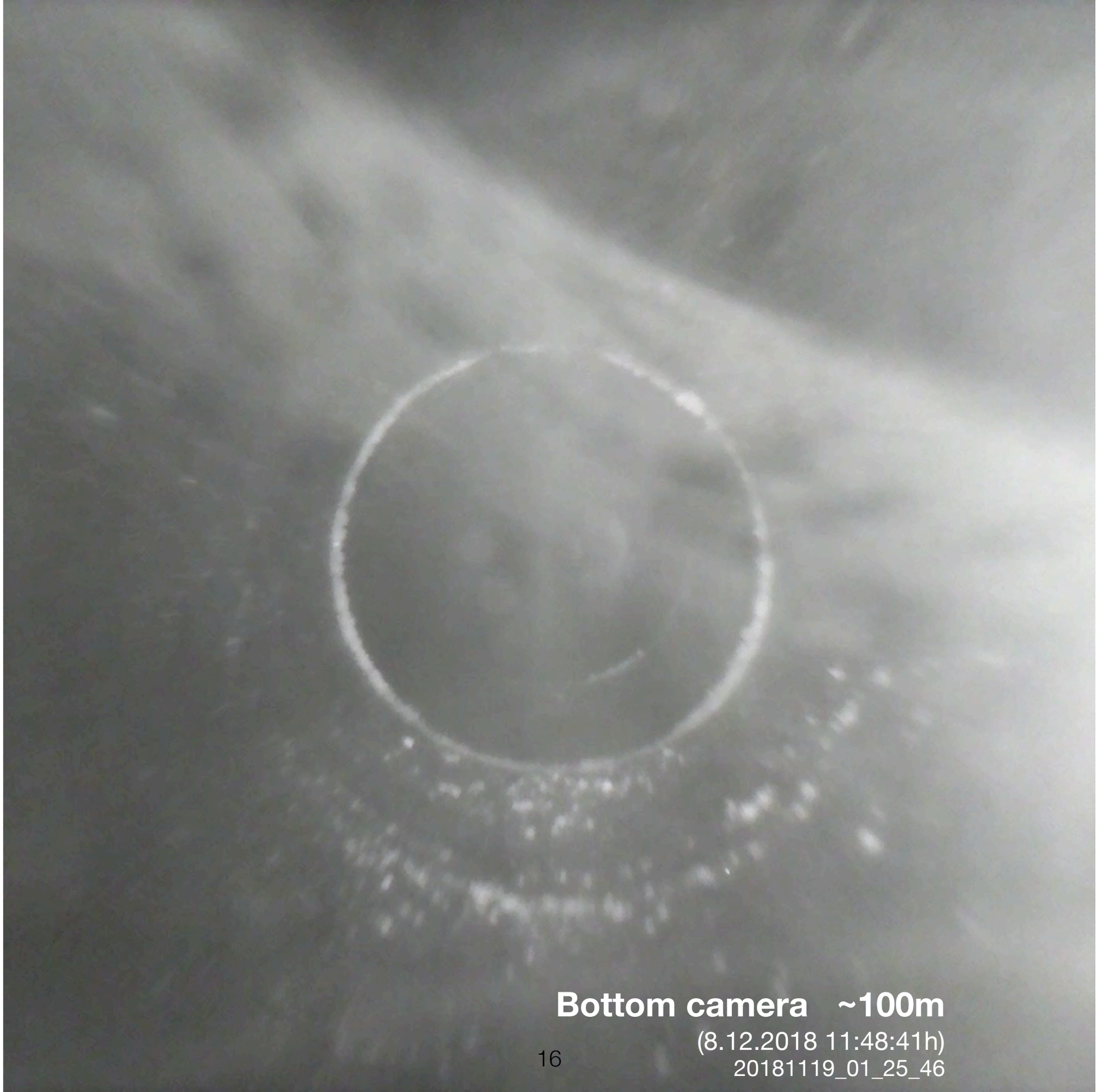
# Backup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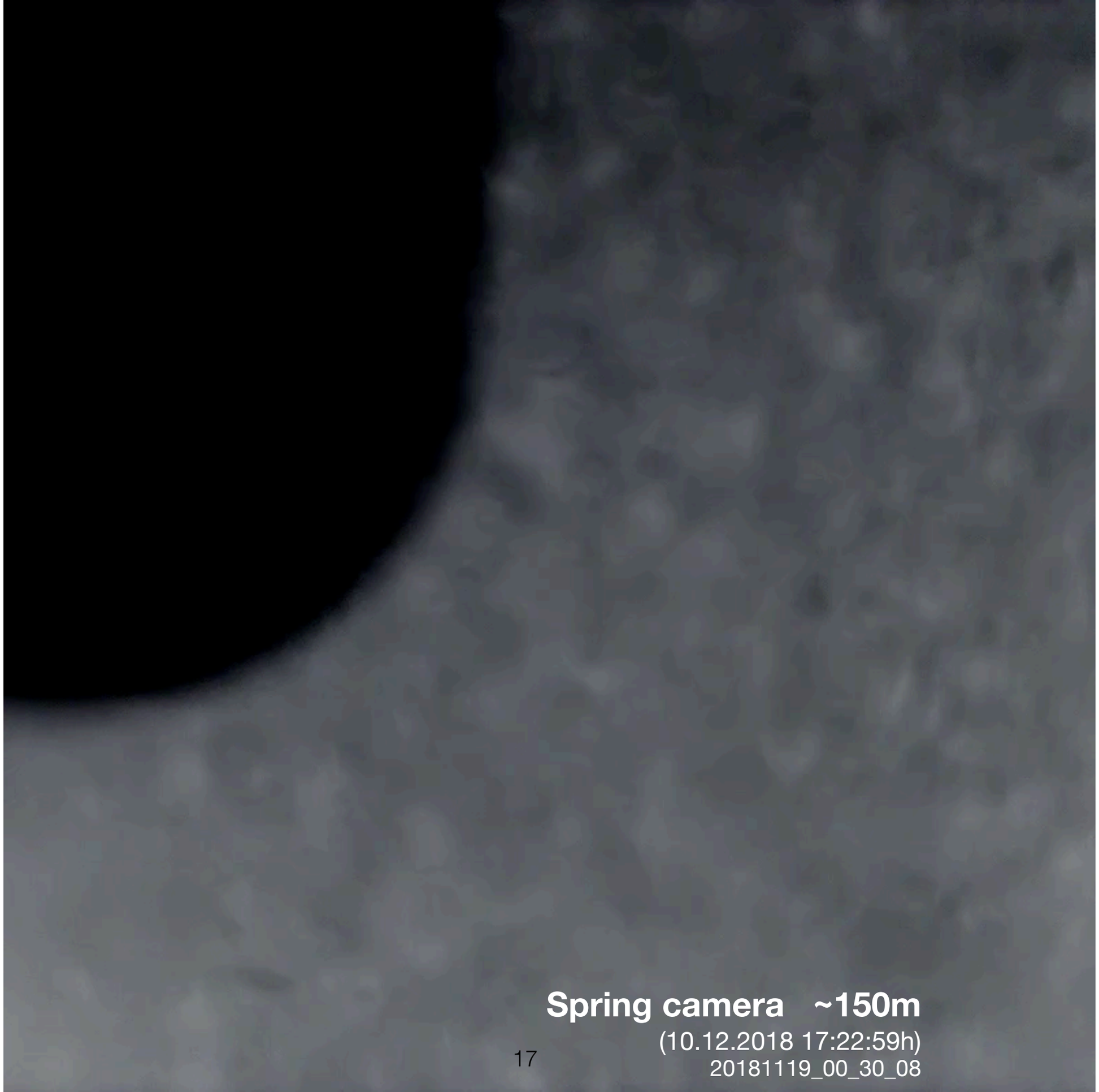
(8.12.2018 11:48:41h)
20181119_01_25_46


Spring camera ~150m
(10.12.2018 17:22:59h)
20181119_00_30_08