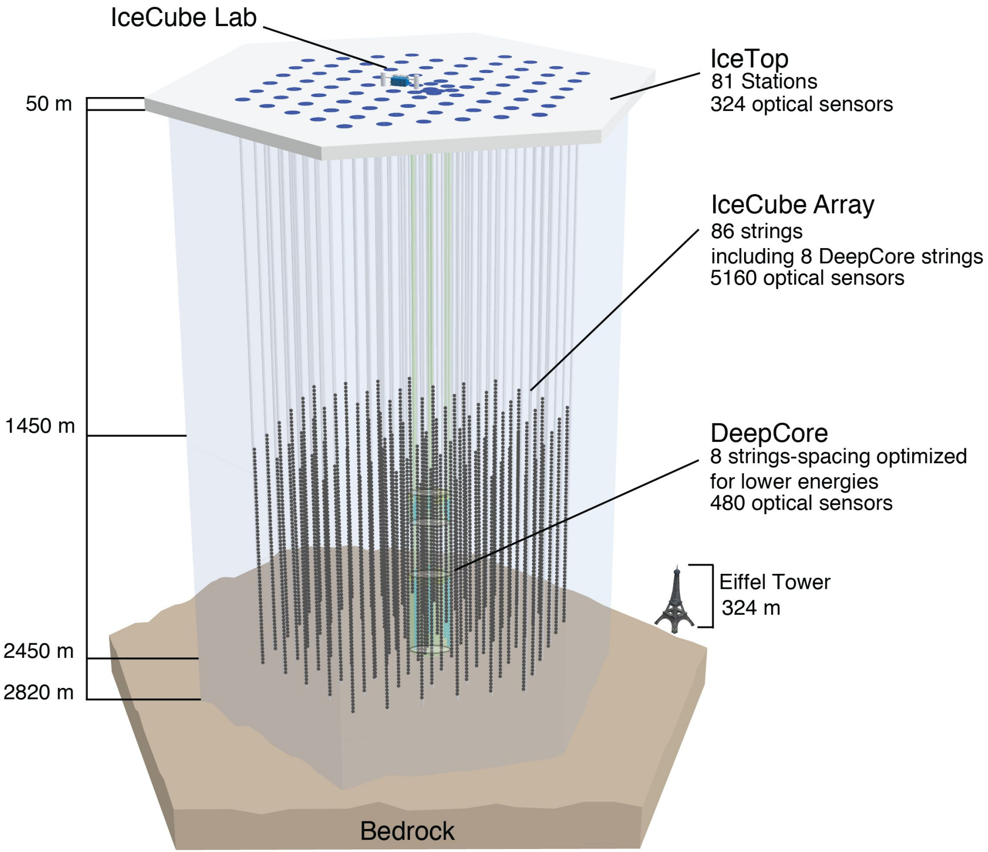
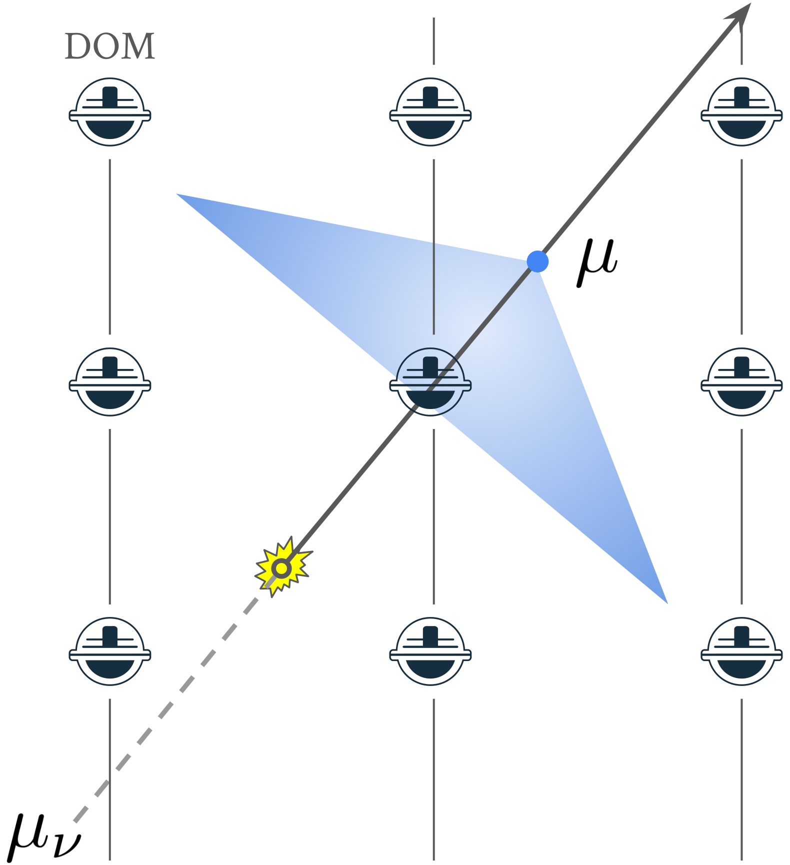
To measure the thermal shock light yield

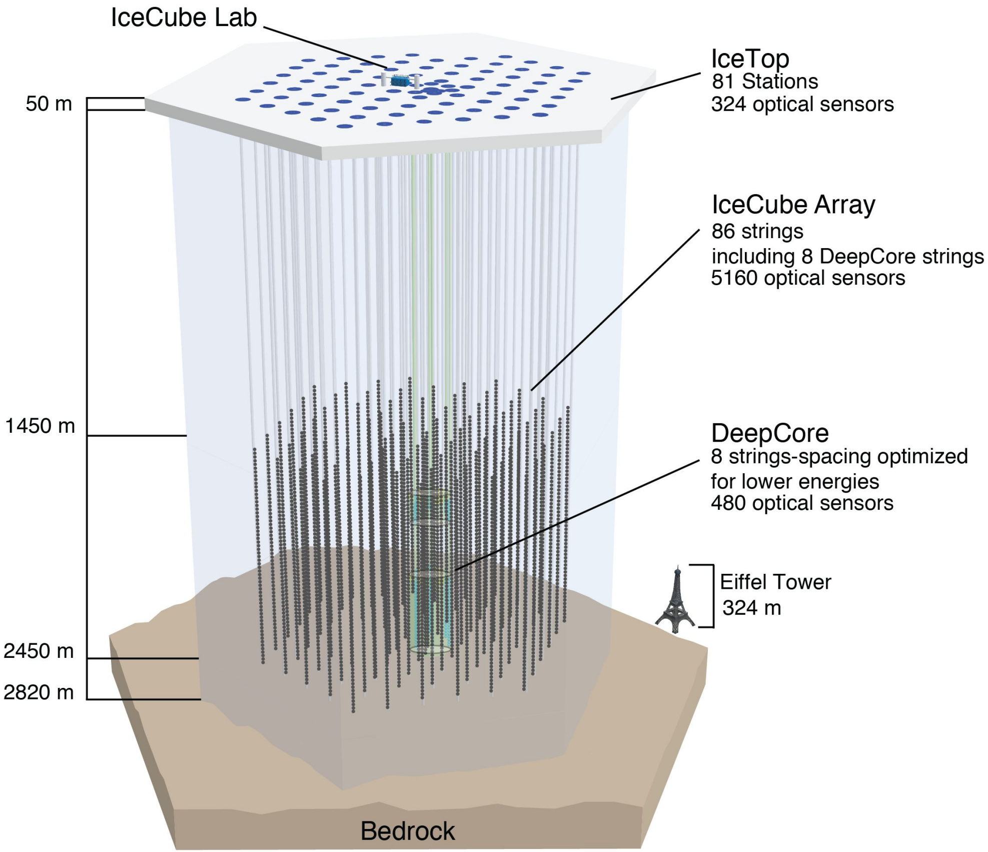
Michael Hrywniak
Partikeldagarna - September 2026

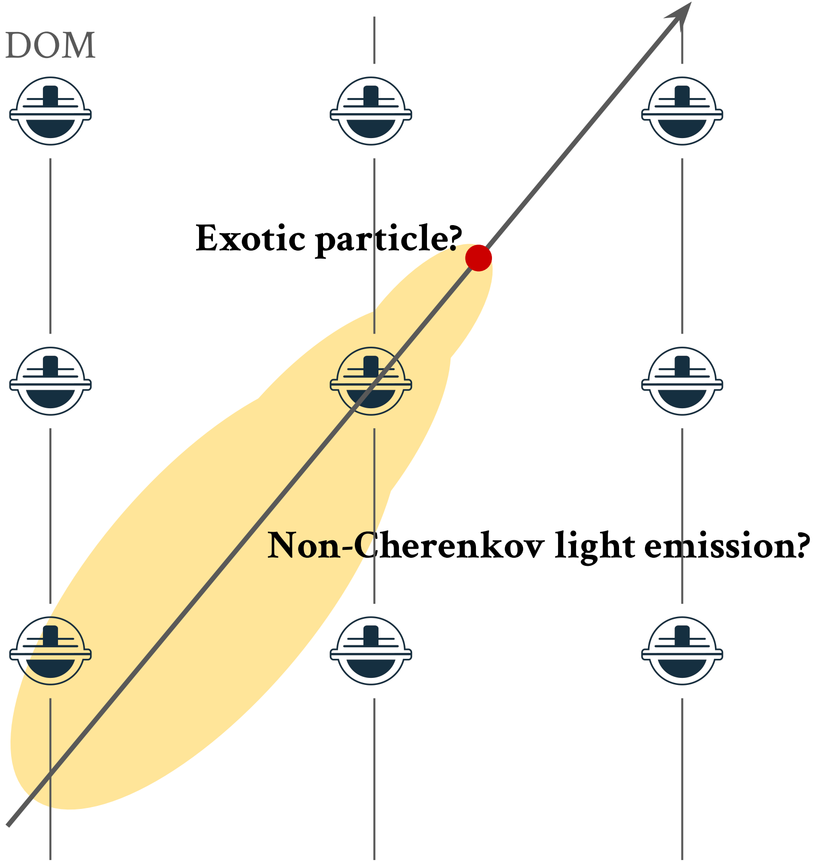
The Icecube Neutrino observatory …



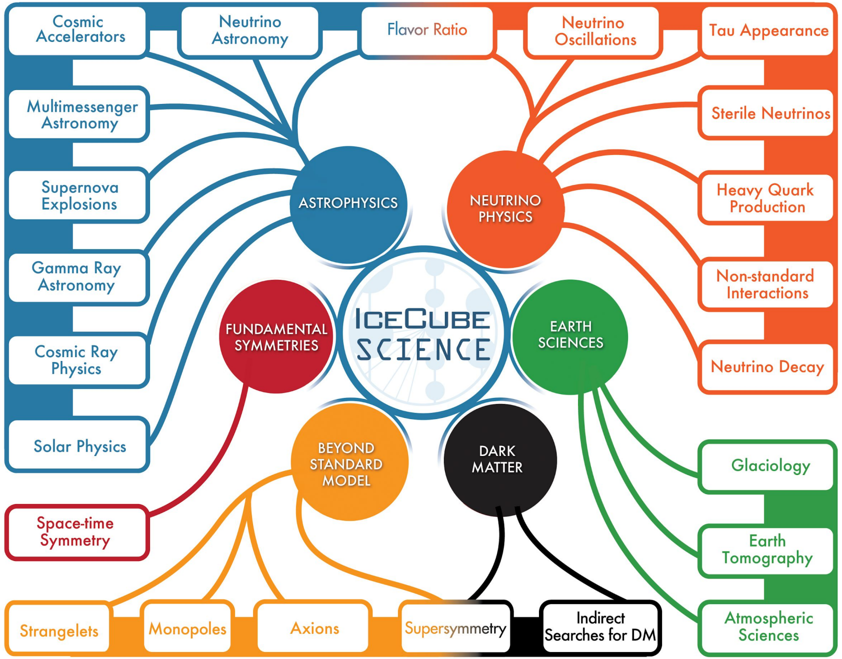


The Icecube Neutrino observatory … may see more than neutrinos





Slow exotic particles

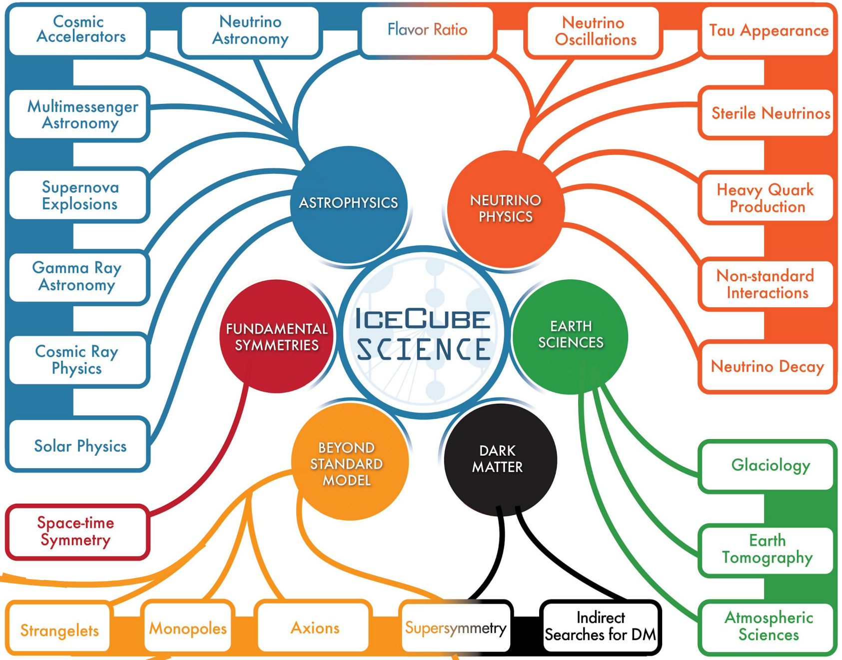


Slow exotic particles

Several BSM models predict exotic particles.

Nuclearites
Stable collections of u-, d-, and s-quarks

Shadow charges
Moving electric field centered around a virtual charge



Magnetic Monopoles
Single magnetic charge, motivated by eg. electric charge quantization

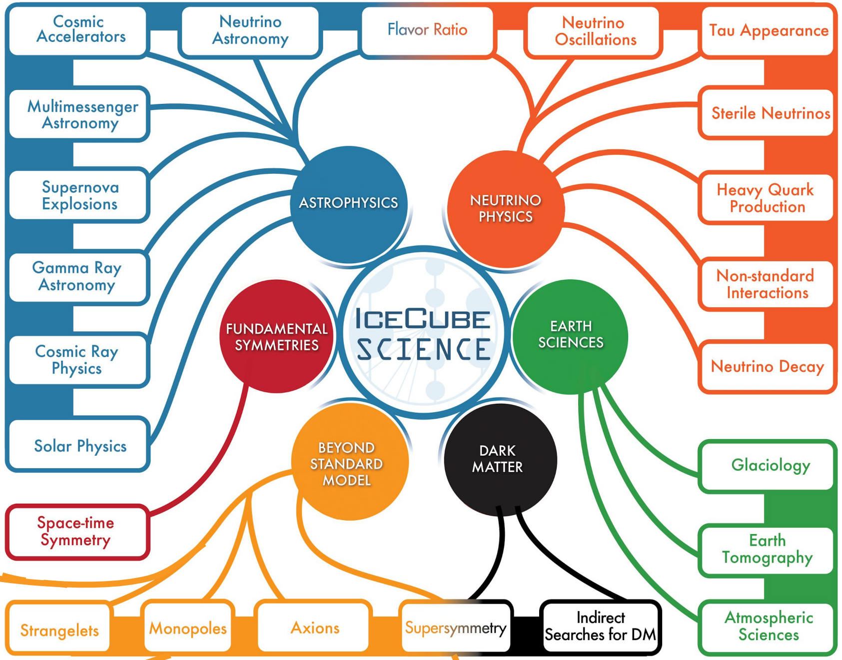
Q-balls
Coherent states of squarks, sleptons and Higgs field, predicted by SUSY

Slow exotic particles

Several BSM models predict exotic particles.

These are particularly massive, consequently they are slow $(v < 0.1c)$

Similar treatment in an Icecube analysis (slow particle trigger)



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Nuclearites and Q-balls

Nuggets of Strange Quark Matter (SQM)

- Aggregates of roughly equal parts of up-, down-, and strange quarks, up to 10^{57} baryons
- Potentially found as Big Bang relics, or remnants of disintegrated neutron stars (strange stars)
- Effectively a large atomic nucleus surrounded by electron cloud
- If part of the Cosmic Ray (CR) flux: Nuclearite

Q-balls

- Non-topological solitons: coherent states of squarks, sleptons, and Higgs field
- Natural consequence of minimal extensions to SUSY
- Carry conserved charge Q (possibly neutralized by electron "atmosphere")

Overall different properties, but similar interaction with matter

Thermal shock as light production mechanism

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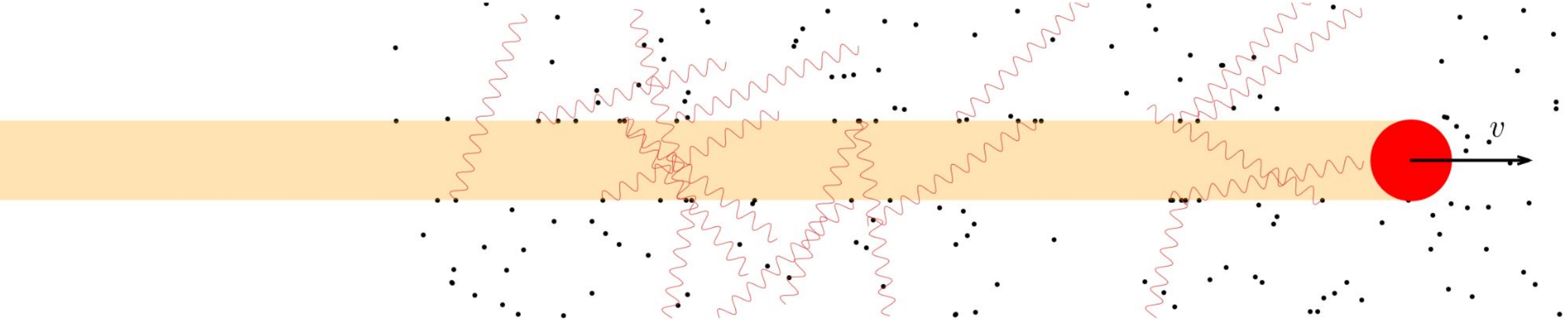

Thermal shock as light production mechanism

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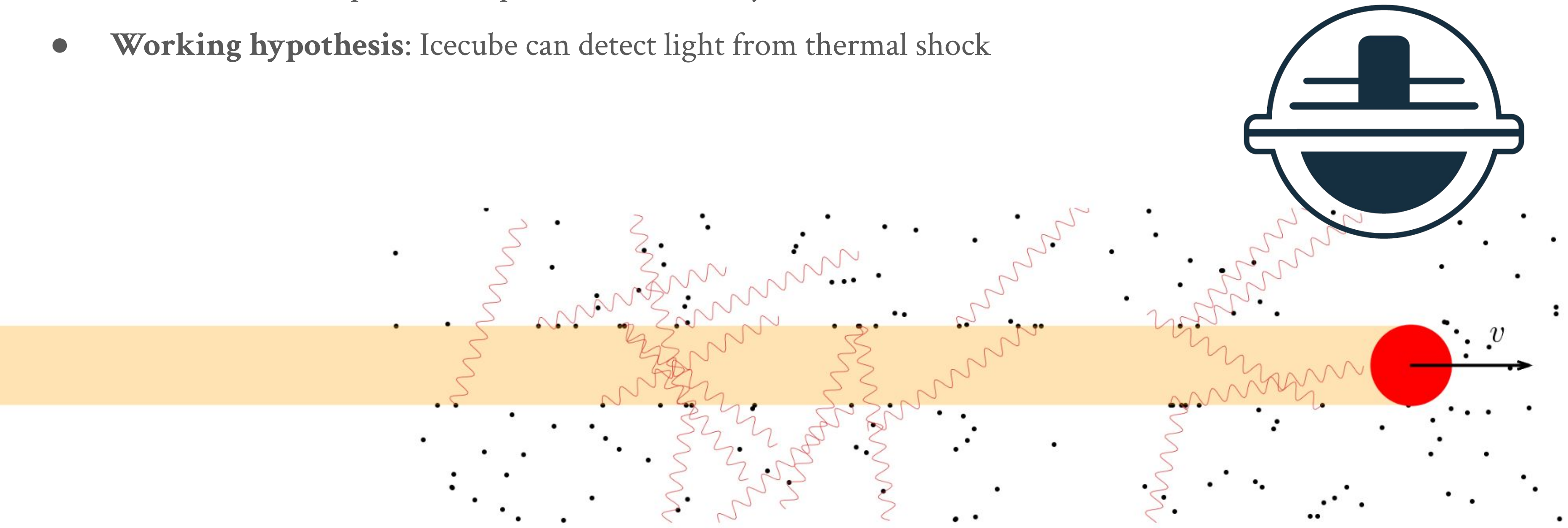
- **Working hypothesis**: Icecube can detect light from thermal shock



Thermal shock light yield

Energy deposition proportional to

- Particle cross-section
- Medium density
- Particle velocity

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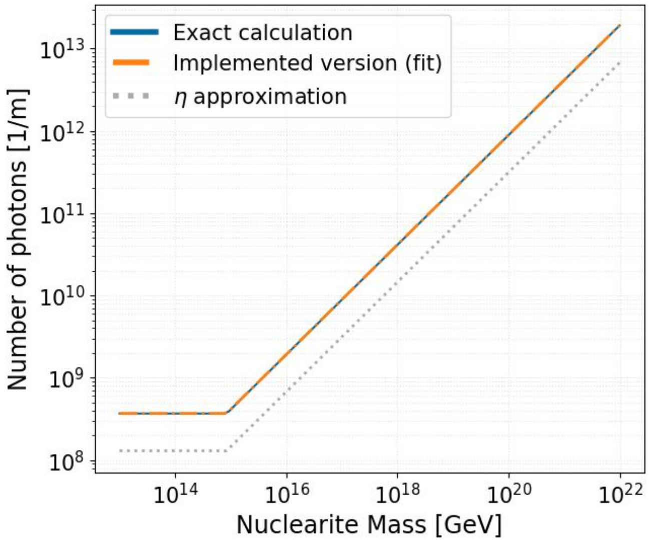
Proportionality constant, “Light Yield”

- Derived from simple thermodynamical assumptions
- **Not actually known**

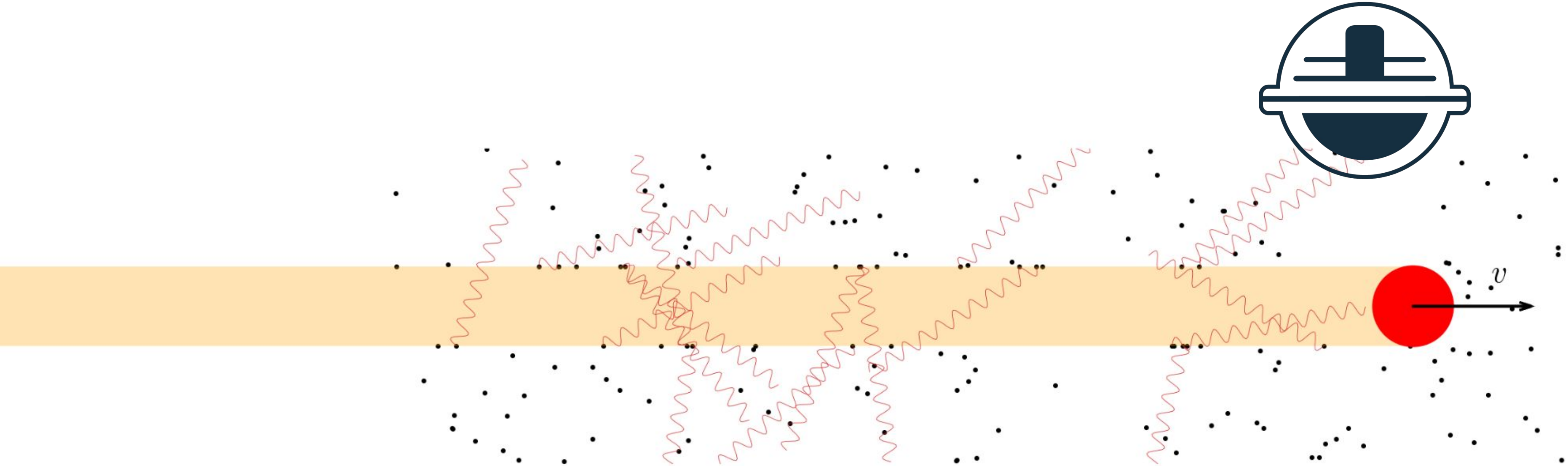
$$\eta \approx 3 \cdot 10^{-5}$$



Credit: Nick Jannis Schmeisser

Goal: Measure the light yield experimentally

- Need some way to induce thermal shock in ice



Goal: Measure the light yield experimentally

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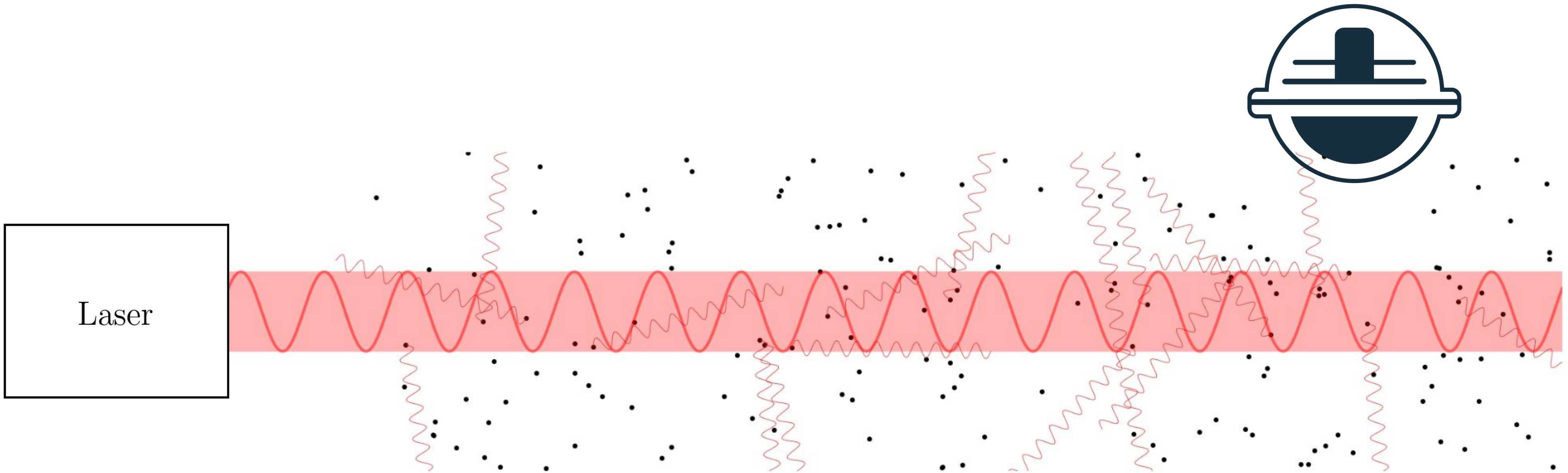
- Use powerful, ultra-short pulsed laser to simulate particle, generate plasma
- Count emitted photons with PMT



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- **Construct measurement setup**

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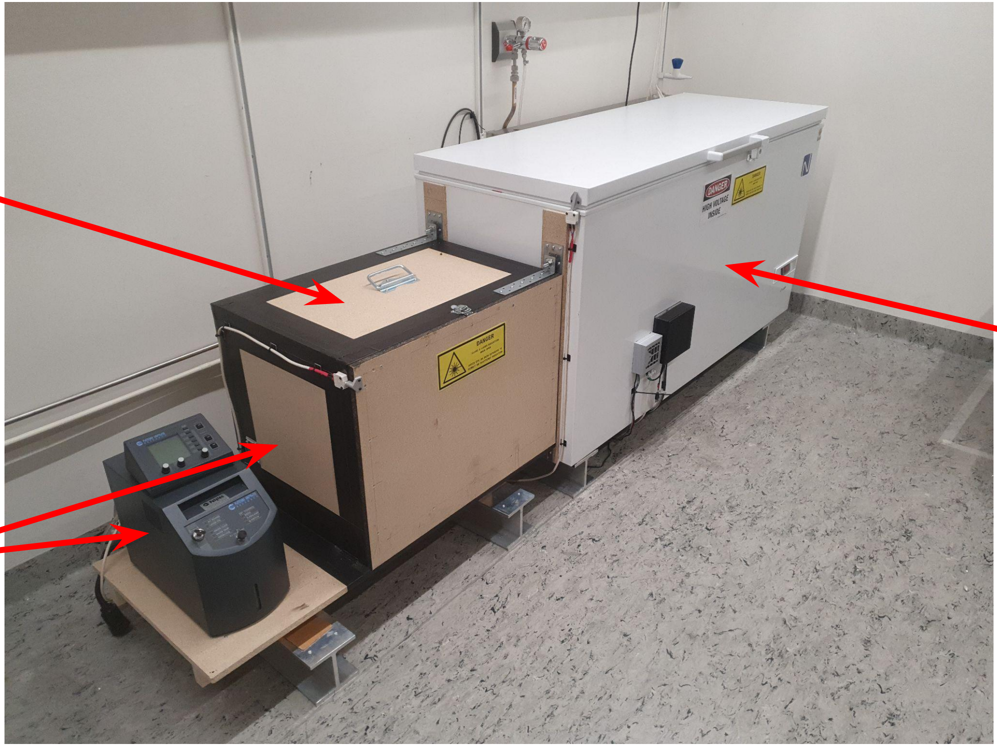
Laser enclosure



PMT enclosure
& test chamber

Nd:YAG
laser

Light yield measurement setup

Polaris II Nd:YAG laser

- 1064 nm
- 5 ns pulses
- 7 **MW of peak power**

Beam pipe

- 1000 nm low pass filters

Ice sample

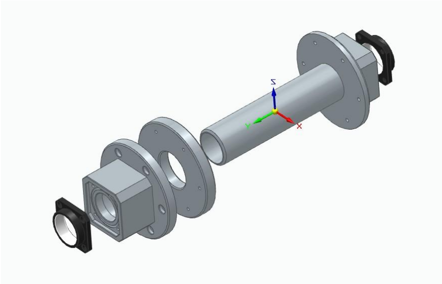
- Ultra-pure water
- Optically clear

Photomultiplier

- Photon counting
- 50 mm diameter

Dark box and thermal control chamber

- Insulates PMT from ambient light
- Holds temperature in the range of antarctic ice (-25 C – -45 C)



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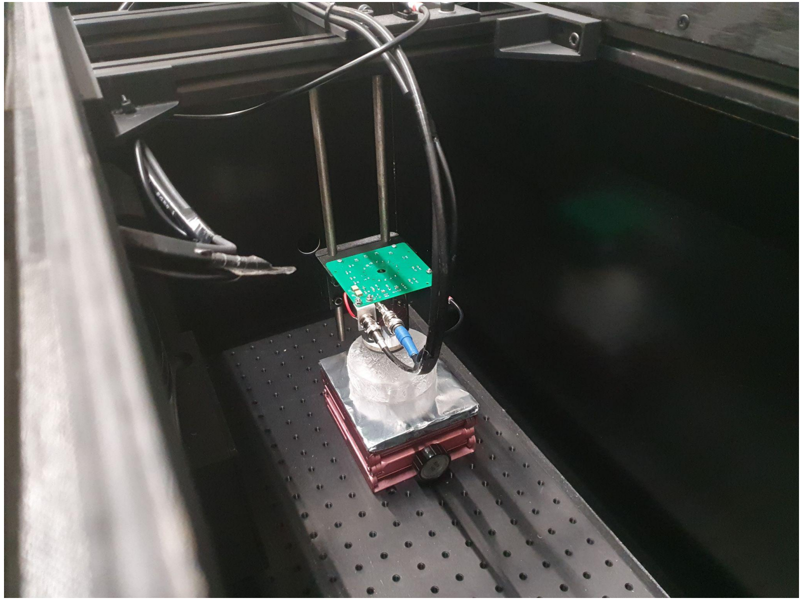

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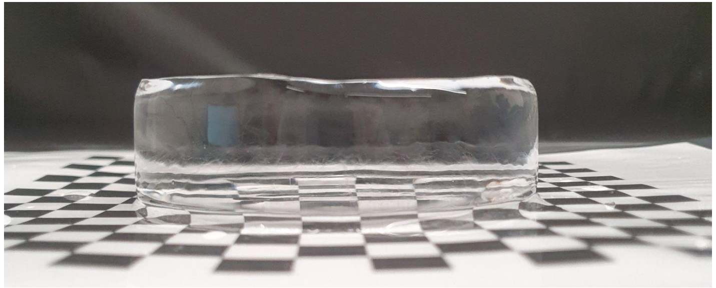

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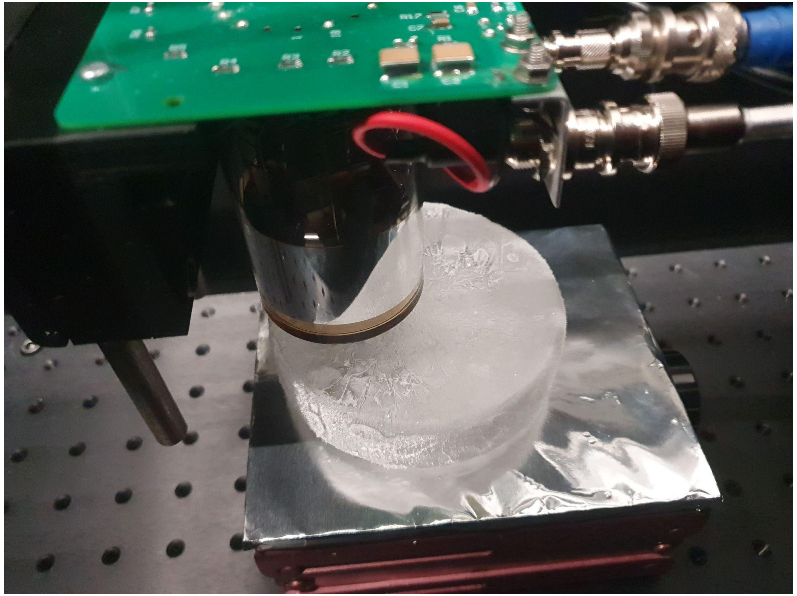

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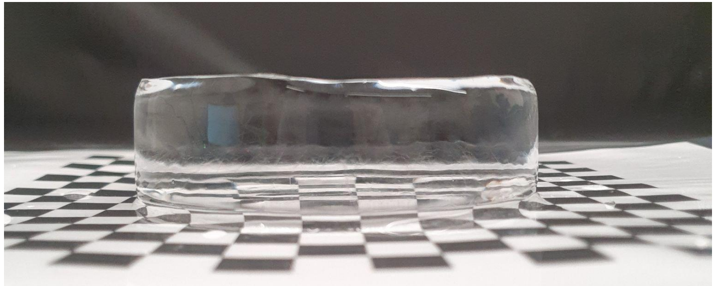

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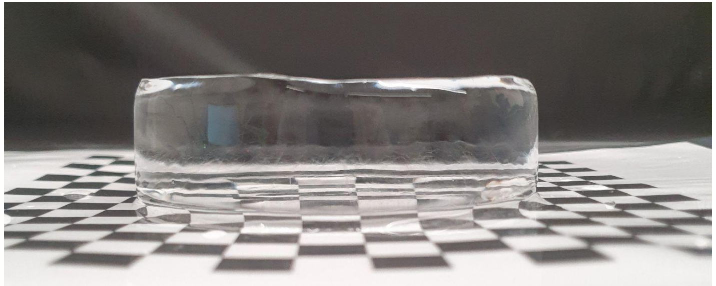
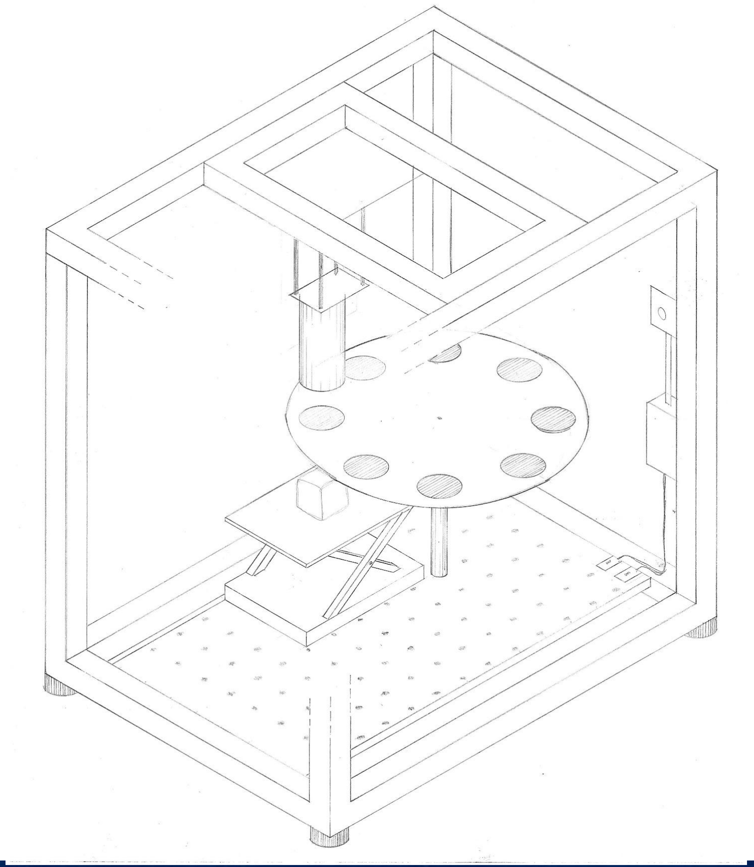


Future installations: Filter wheel + acoustic measurement

- Placed between ice sample and PMT
- Measure light yield at select wavelengths
- Estimate spectrum of light produced by thermal shock
    - Check if black-body → Estimate plasma temperature

- Embed acoustic sensors in ice sample
- Measure sound waves generated by thermal shock

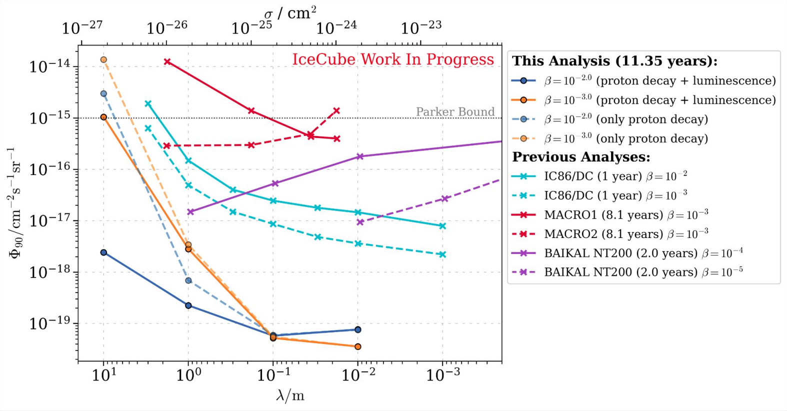


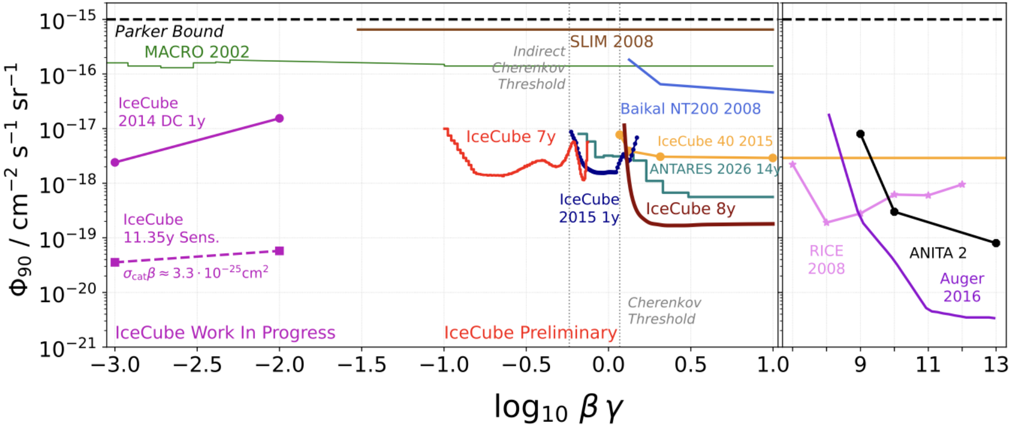
Outlook for the slow particles group

Ongoing analyses in the slow particles group:

- Monopoles
- Nuclearites (numerically estimated light yield)
- Shadow charges
- Q-balls

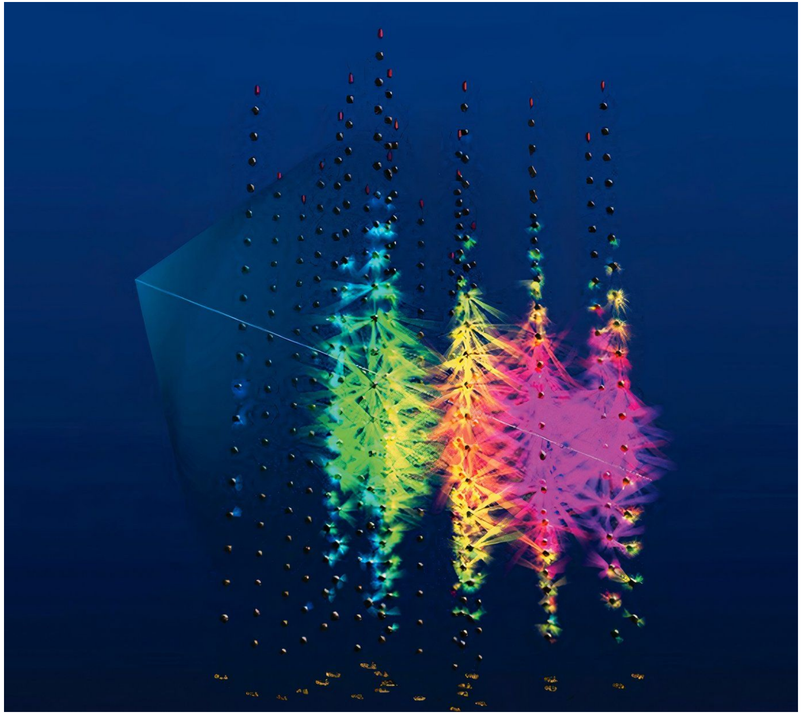
Analyses very close to unblinding



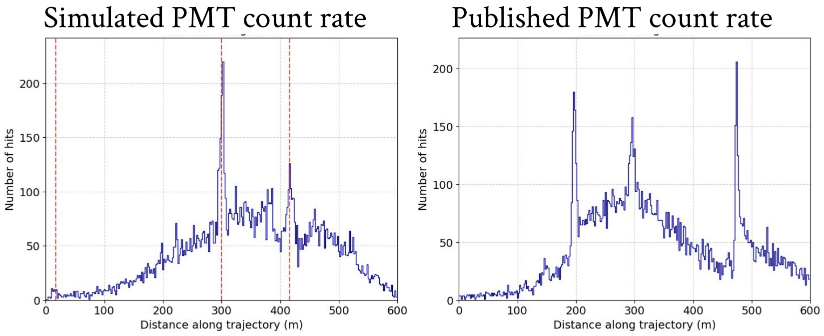


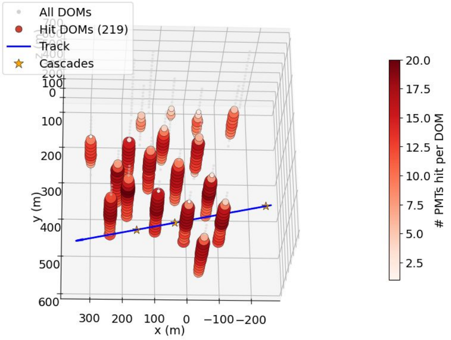
Could the KM3NeT event be exotic?

Potentially the highest energy muon observed…



…potentially cannot be ruled out as a relativistic monopole





Work by Gloria Zhang

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