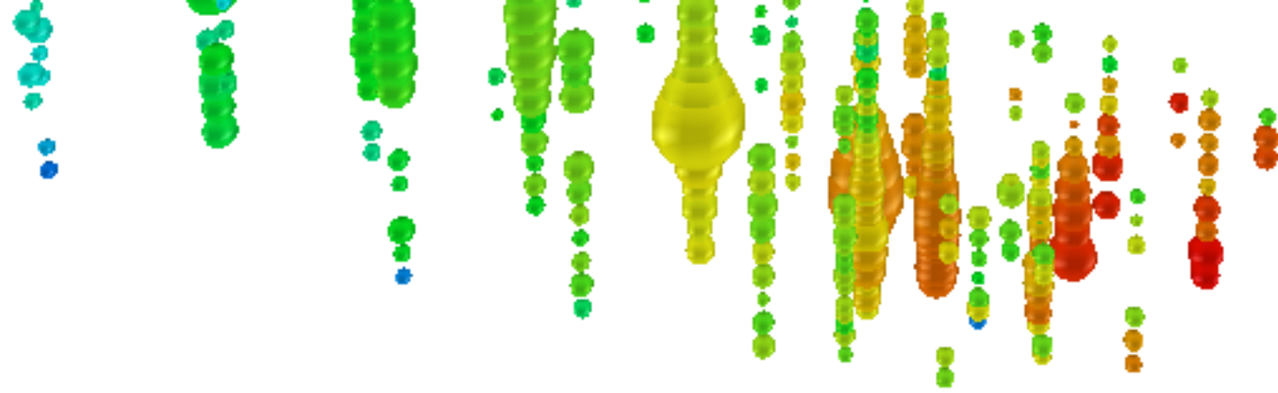
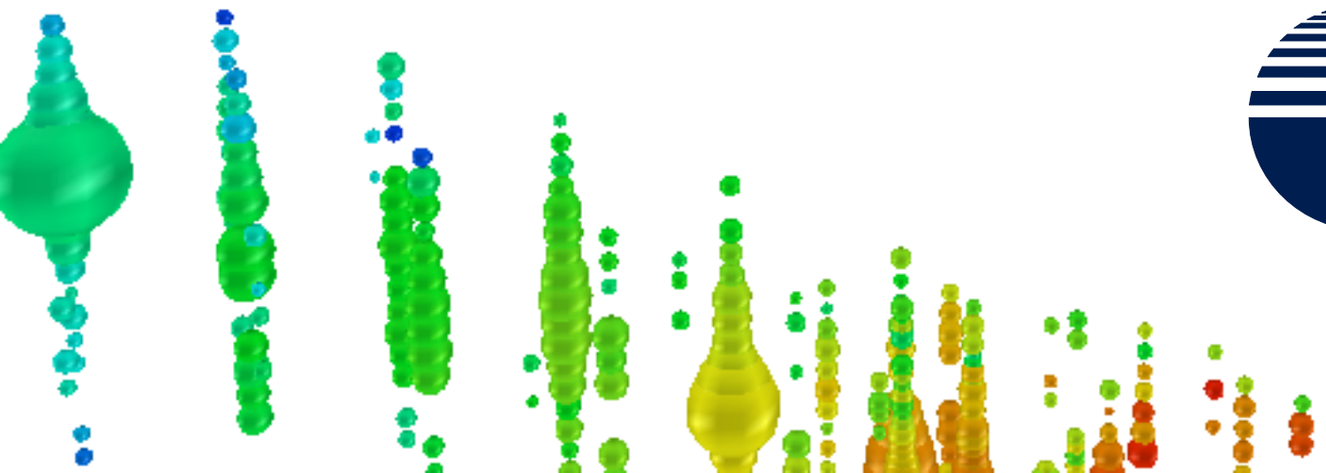


BERGISCHE
UNIVERSITÄT
WUPPERTAL

Luminescence
as a new detection method for
Magnetic Monopoles

Anna Pollmann

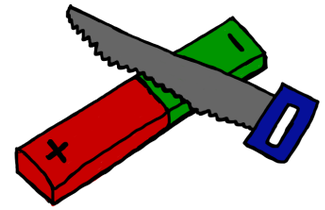


bmb+f - Förderschwerpunkt
Astroteilchenphysik
Großgeräte der physikalischen Grundlagenforschung

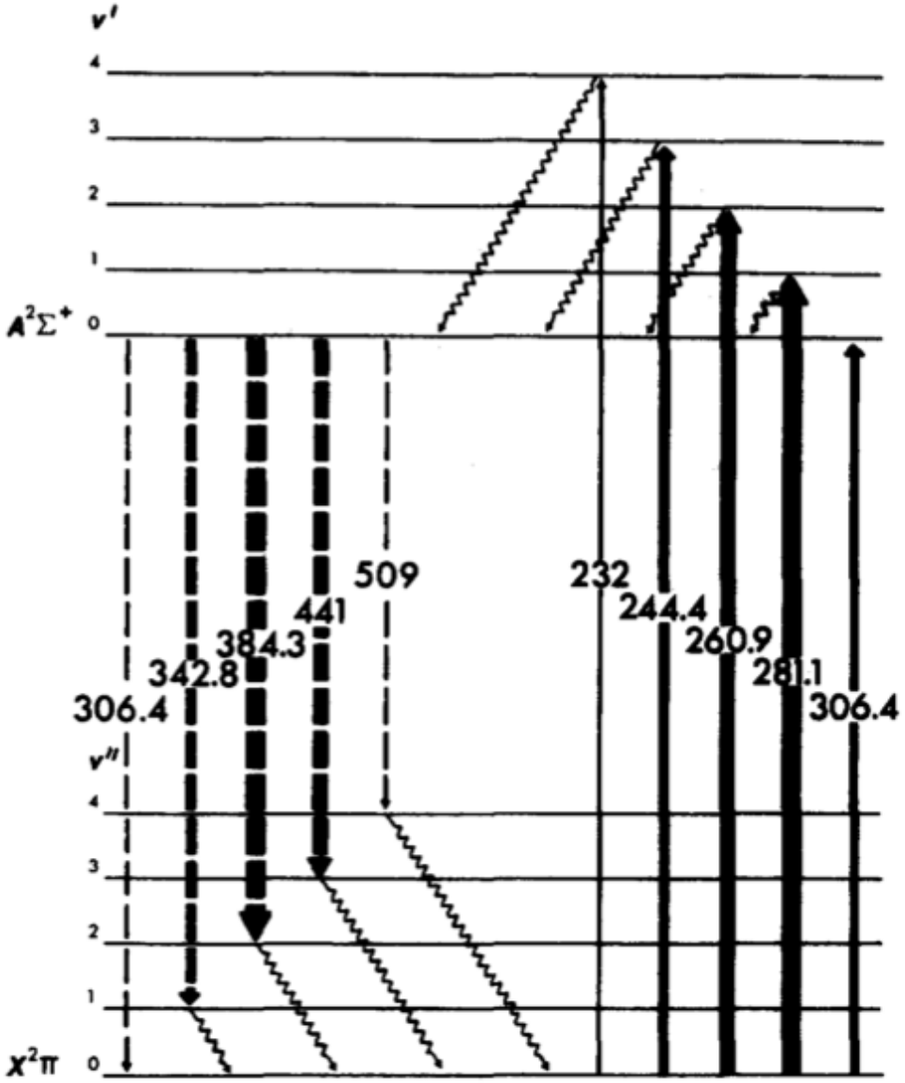
IceCube

anna.pollmann@uni-wuppertal.de

Luminescence of water



OH^- excited states



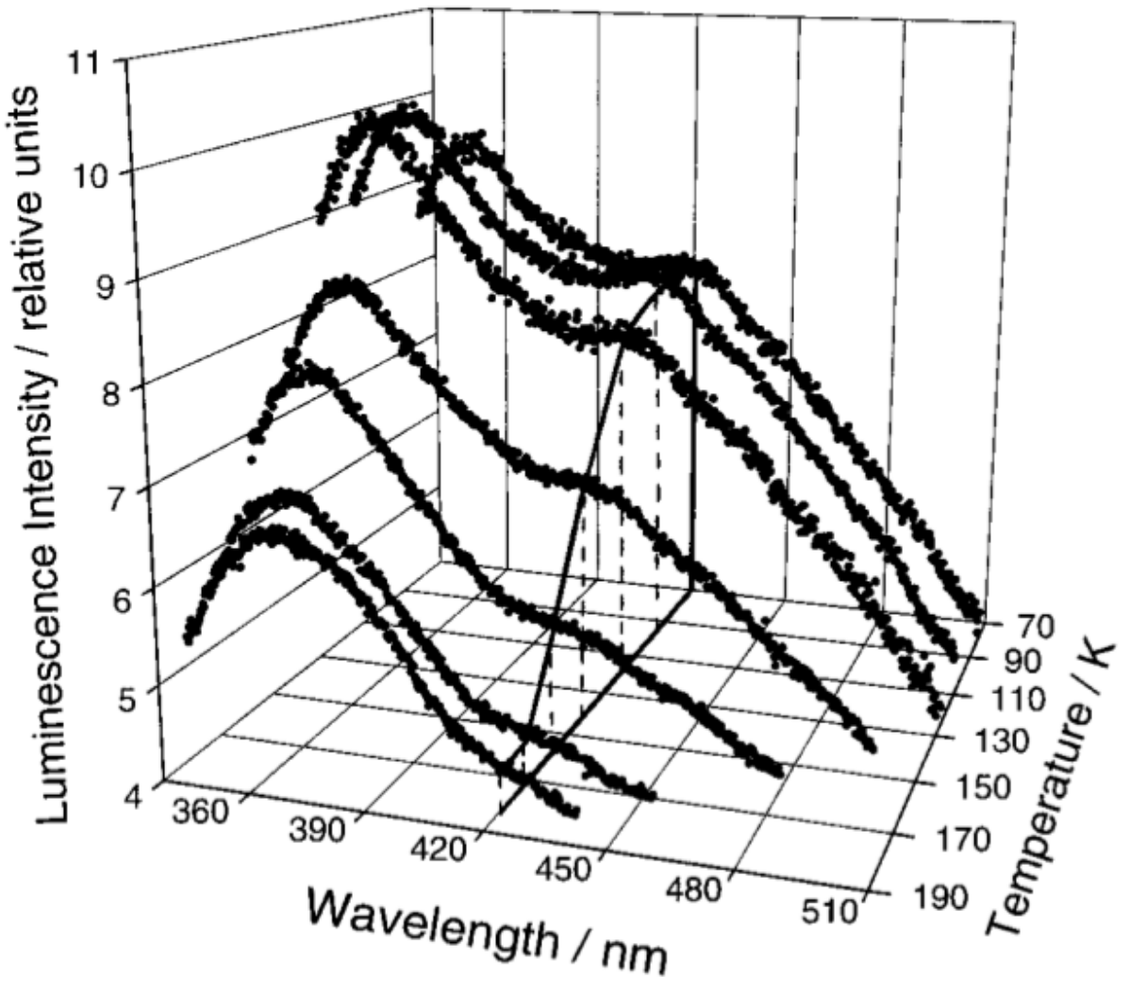
Definition:

- excitation of transparent media by ionizing radiation giving light subsequently

Spectrum:

- Peaks at
  - ~ 290 nm
  - ~ 360 nm
  - ~ 420 nm
  - ~ 550 nm
- Temperature dependent

Luminescence of water



J. Phys. Chem. A, Vol. 101, No. 25, 1997
(UV irradiated purified water)

Definition:

- excitation of transparent media by ionizing radiation giving light subsequently

Spectrum:

- Peaks at
  - ~ 290 nm
  - ~ 360 nm
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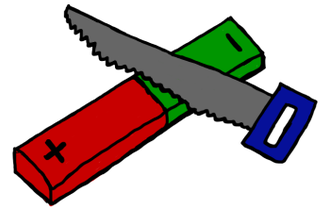
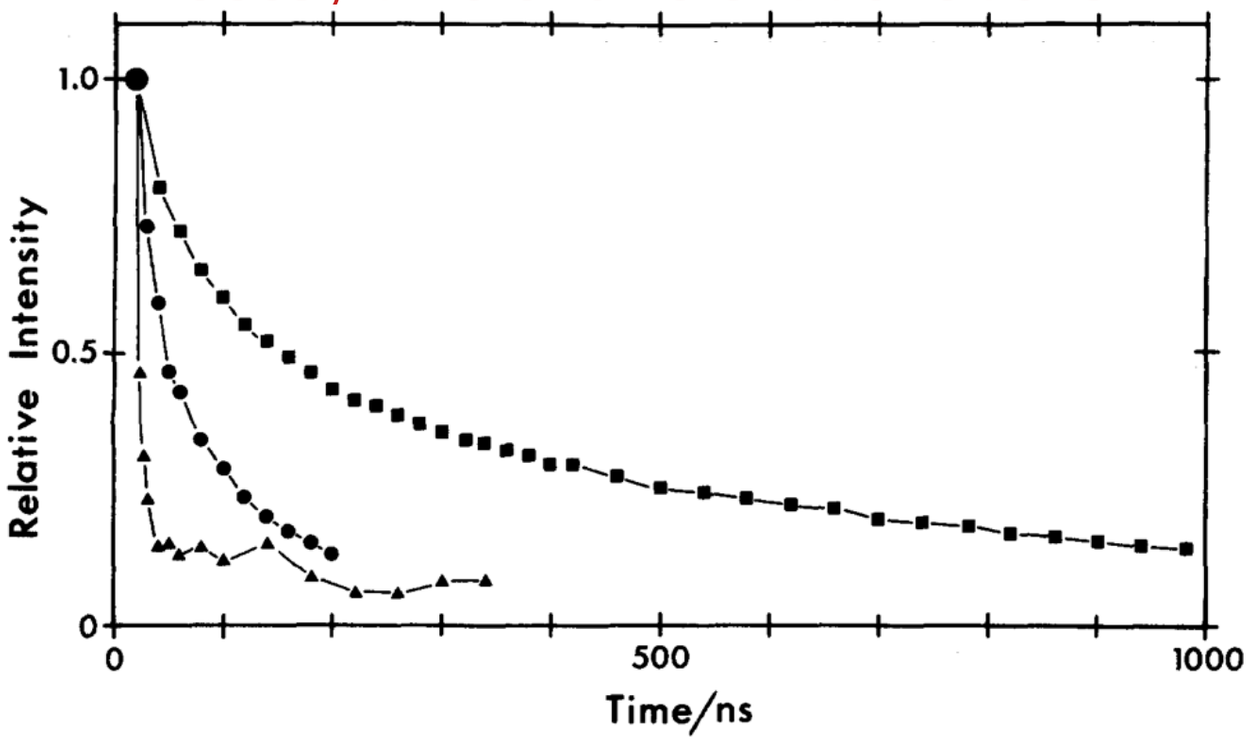
Luminescence of water



decay time of different transitions



Trotman et al., J. Chem. Phys. 85, 2555 (1986)

Definition:

- excitation of transparent media by ionizing radiation giving light subsequently

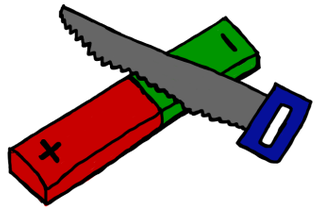
Spectrum:

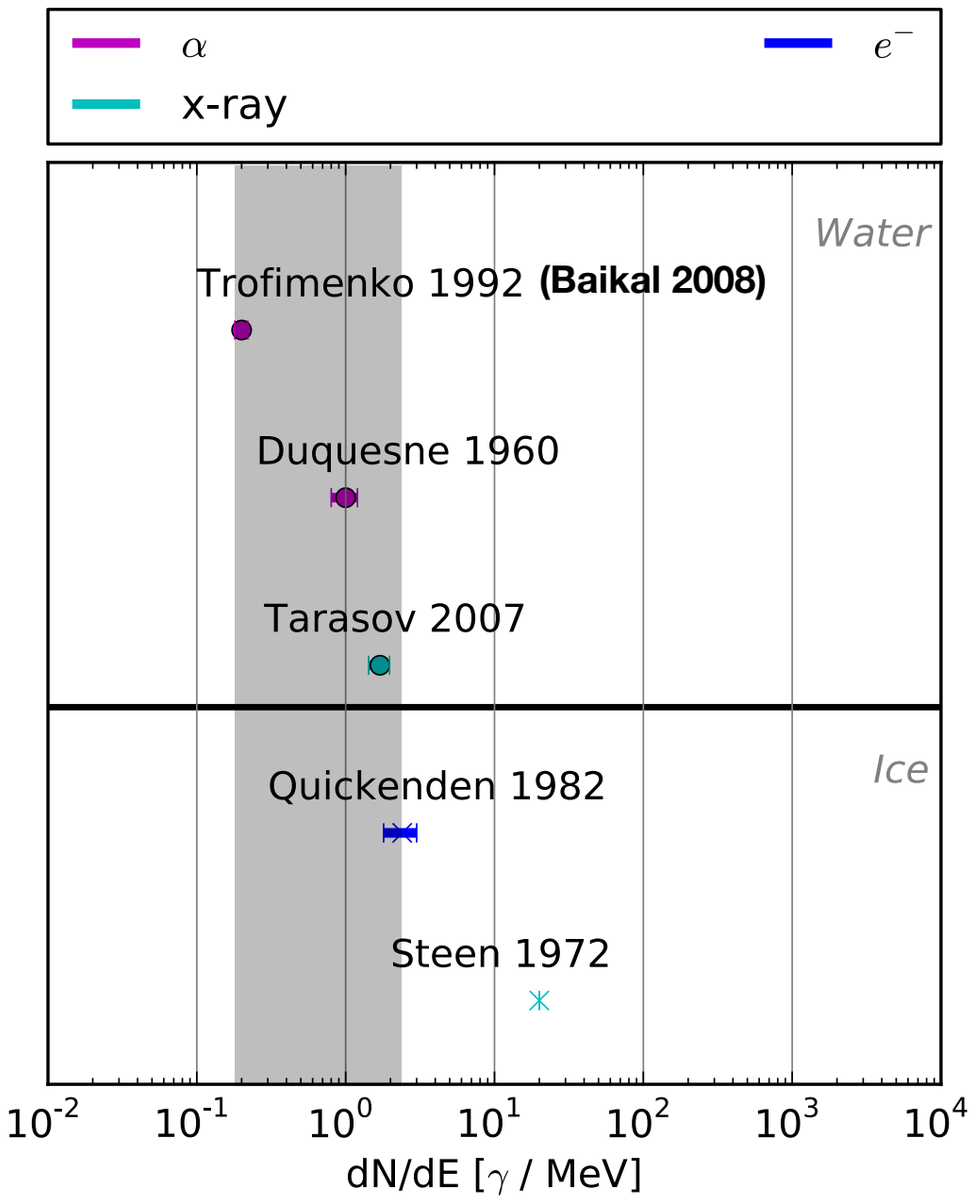
- Peaks at
  - ~ 290 nm
  - ~ 360 nm
  - ~ 420 nm
  - ~ 550 nm
- Temperature dependent

Lifetime:

- nanoseconds to microseconds

Luminescence of water





Definition:

- excitation of transparent media by ionizing radiation giving light subsequently

Spectrum:

- Peaks at
  - ~ 290 nm
  - ~ 360 nm
  - ~ 420 nm
  - ~ 550 nm
- Temperature dependent

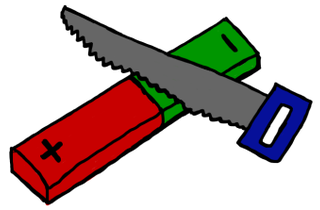
Lifetime:

- O(100)ns - O(1000)ns

Efficiency:

- *Baikal* 0.2 γ / MeV
- *Quickenden* 2.4 γ / MeV

Magnetic monopoles



- elemental magnetic charge (Dirac)

  $g_D = e / 2\,\alpha \approx 68.5\,e$

- topological defects with huge mass created
  - shortly after the Big Bang

    10^{13} GeV ≦ M_{MM} ≦ 10^{19} GeV

  - in intermediate stages of symmetry breaking

    10^{7} GeV ≦ M_{MM} ≦ 10^{13} GeV

  - at accelerators (electroweak and other)

    M_{MM} ~ TeV

- acceleration in magnetic fields gives

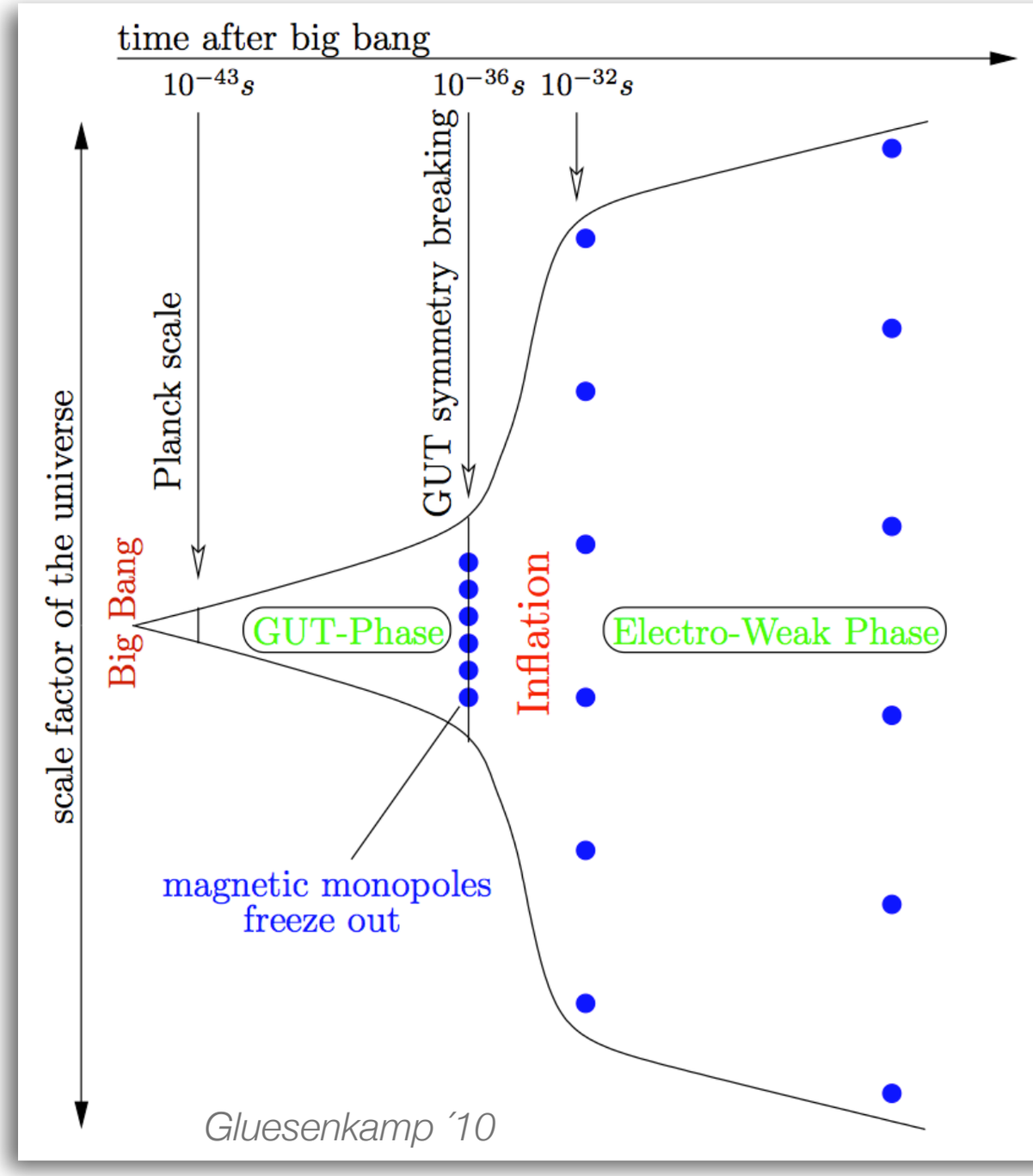
  E_{kin} ≦ 10^{13} GeV

  - trapping around galaxy, sun, Earth

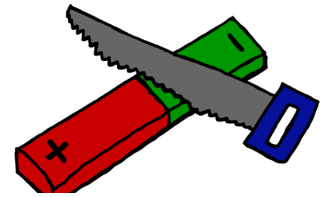
    v ~ 10^{-3} / 10^{-4} / 10^{-5} c

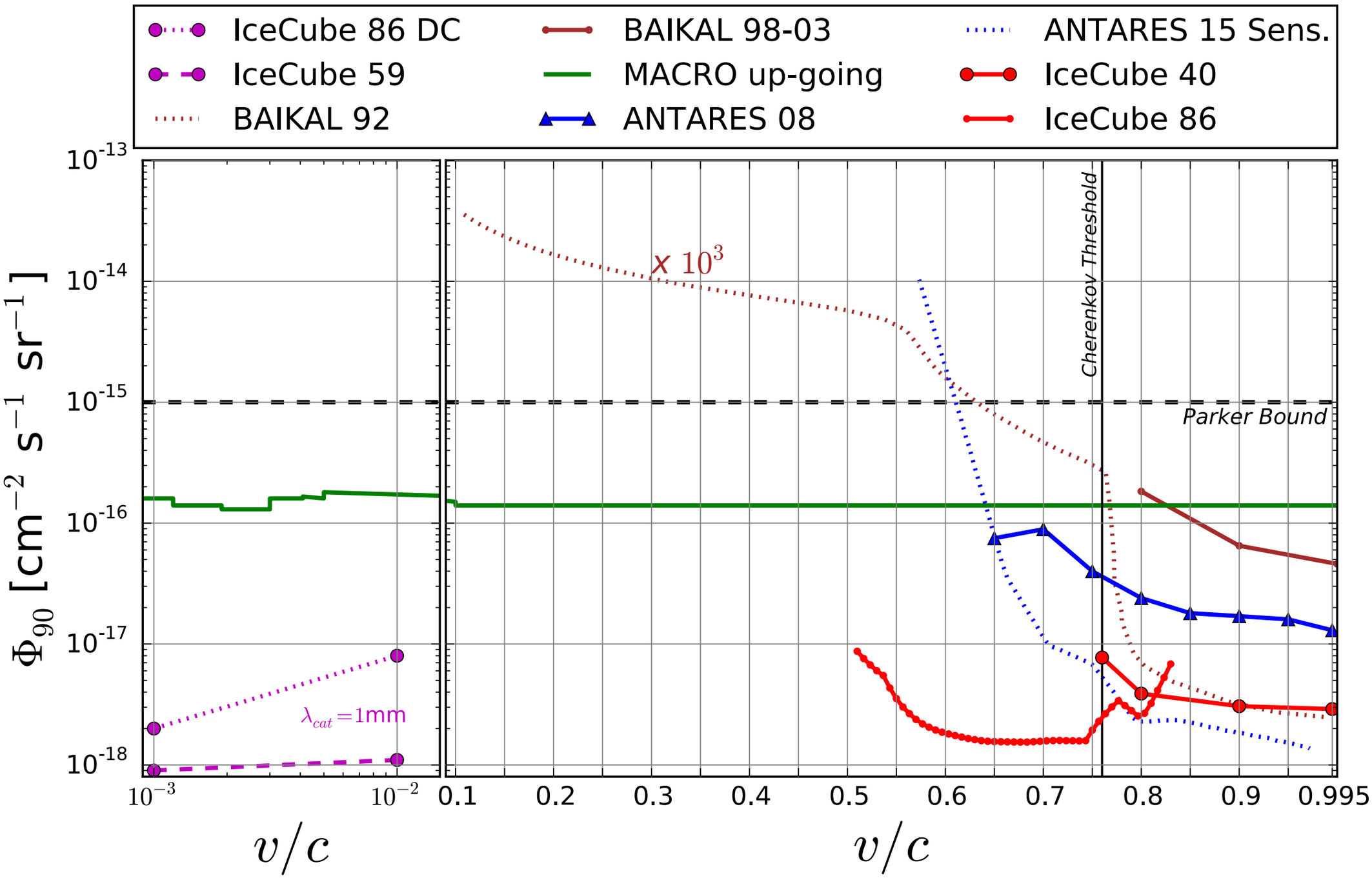
- ionization power

  E_{dep} ~g^2 (Muons: ~ Z^2 / β^2)



Monopole - Searches / Interactions





Non-relativistic

catalysis of proton decay required (Cherenkov light)

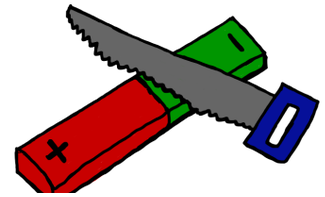
Mildly relativistic

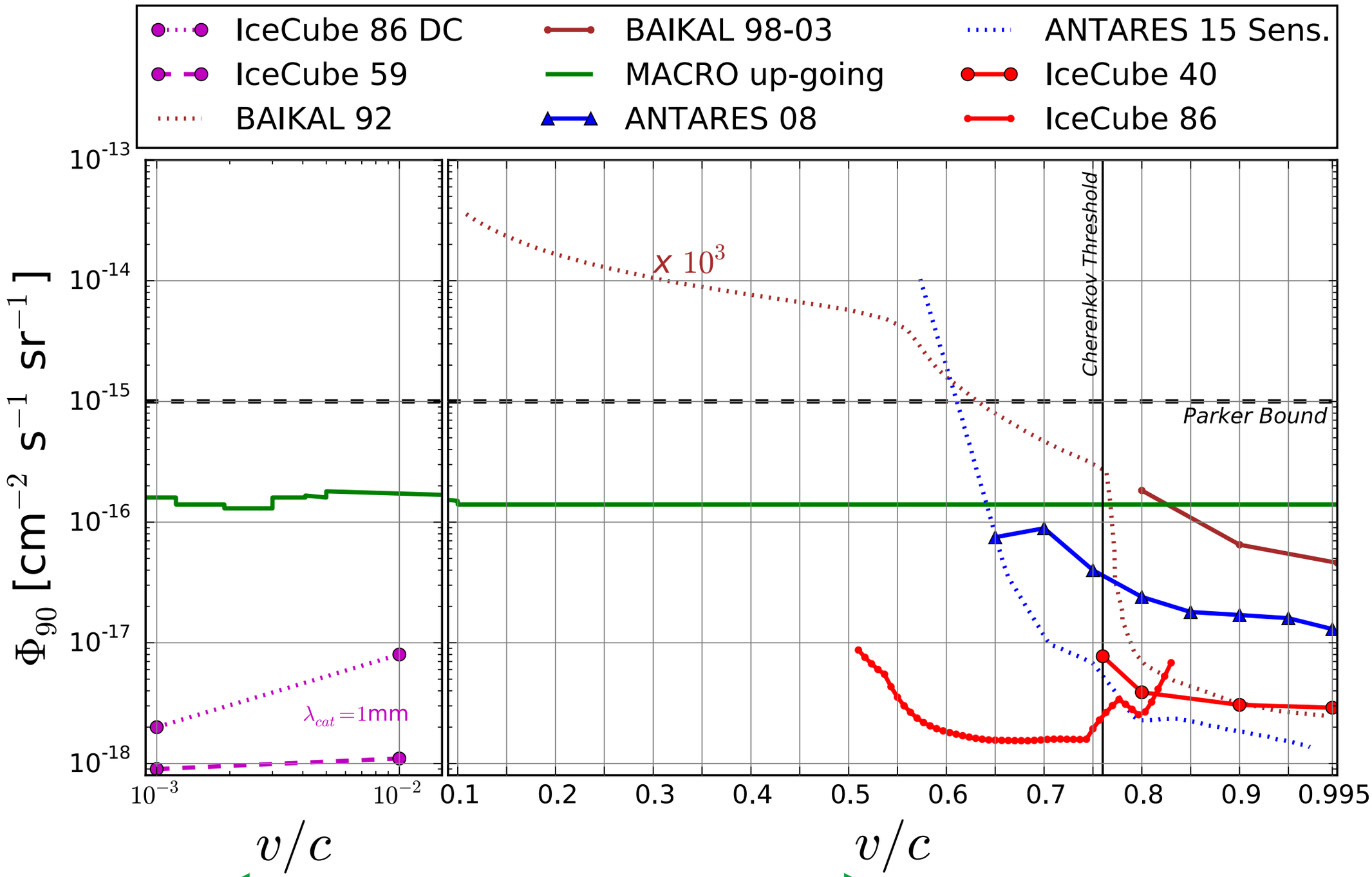
indirect Cherenkov light

Highly relativistic

direct Cherenkov light

Monopole - Searches / Interactions





Non-relativistic

catalysis of proton decay required (Cherenkov light)

Low relativistic

luminescence

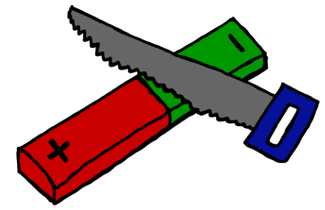
Mildly relativistic

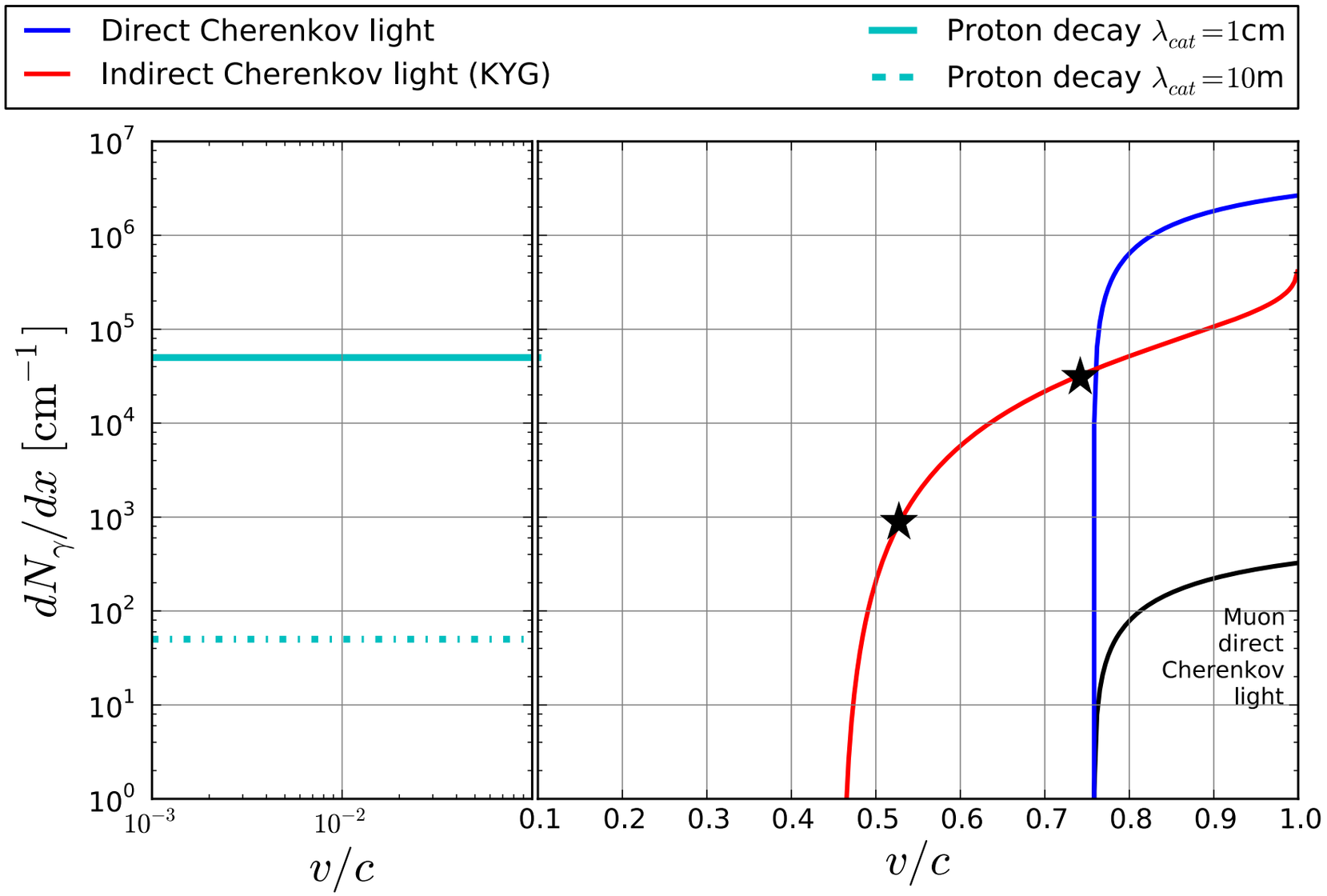
indirect Cherenkov light

Highly relativistic

direct Cherenkov light

Light yield of Monopoles





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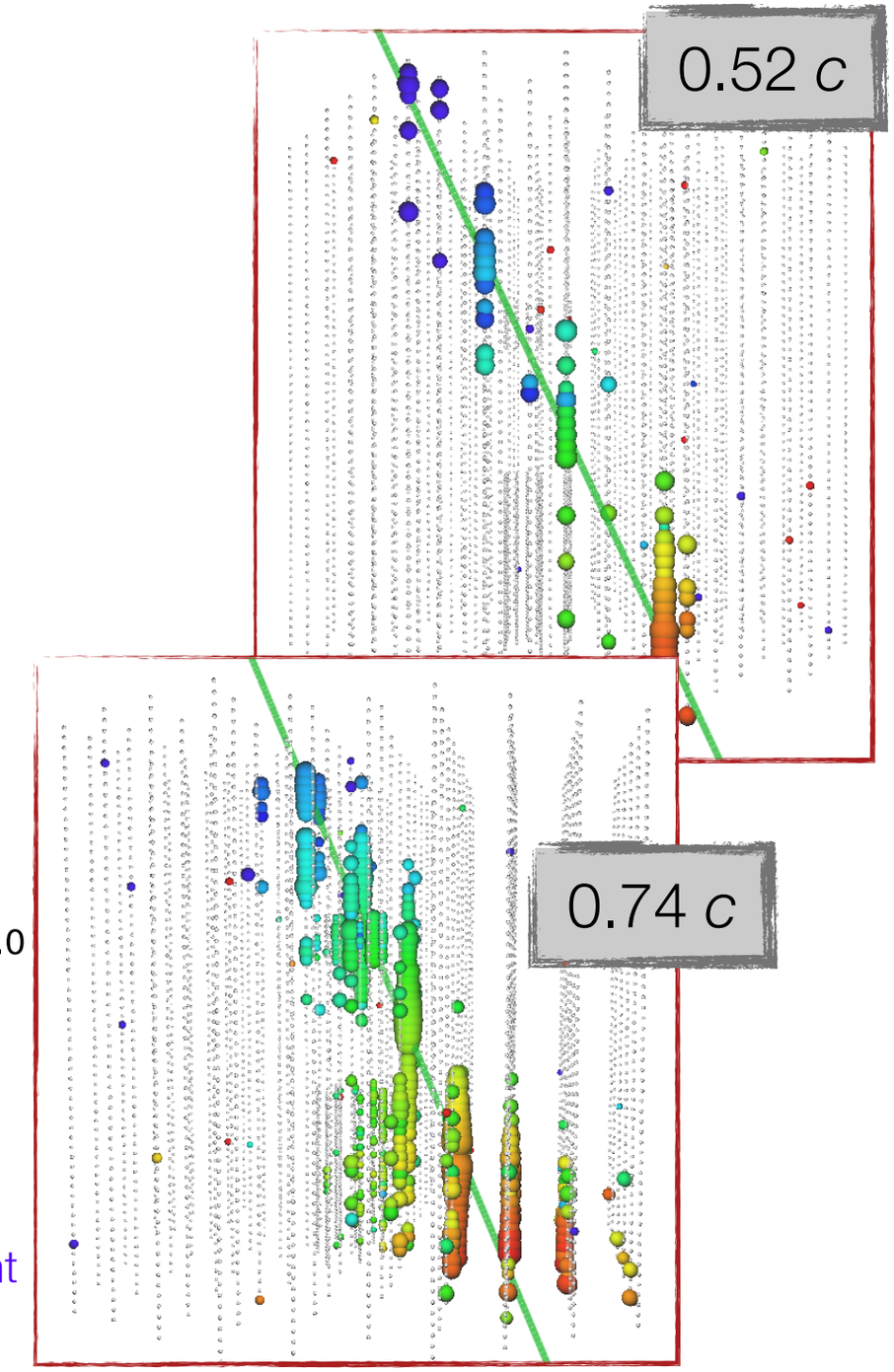
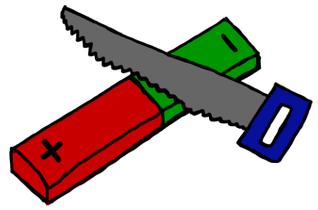
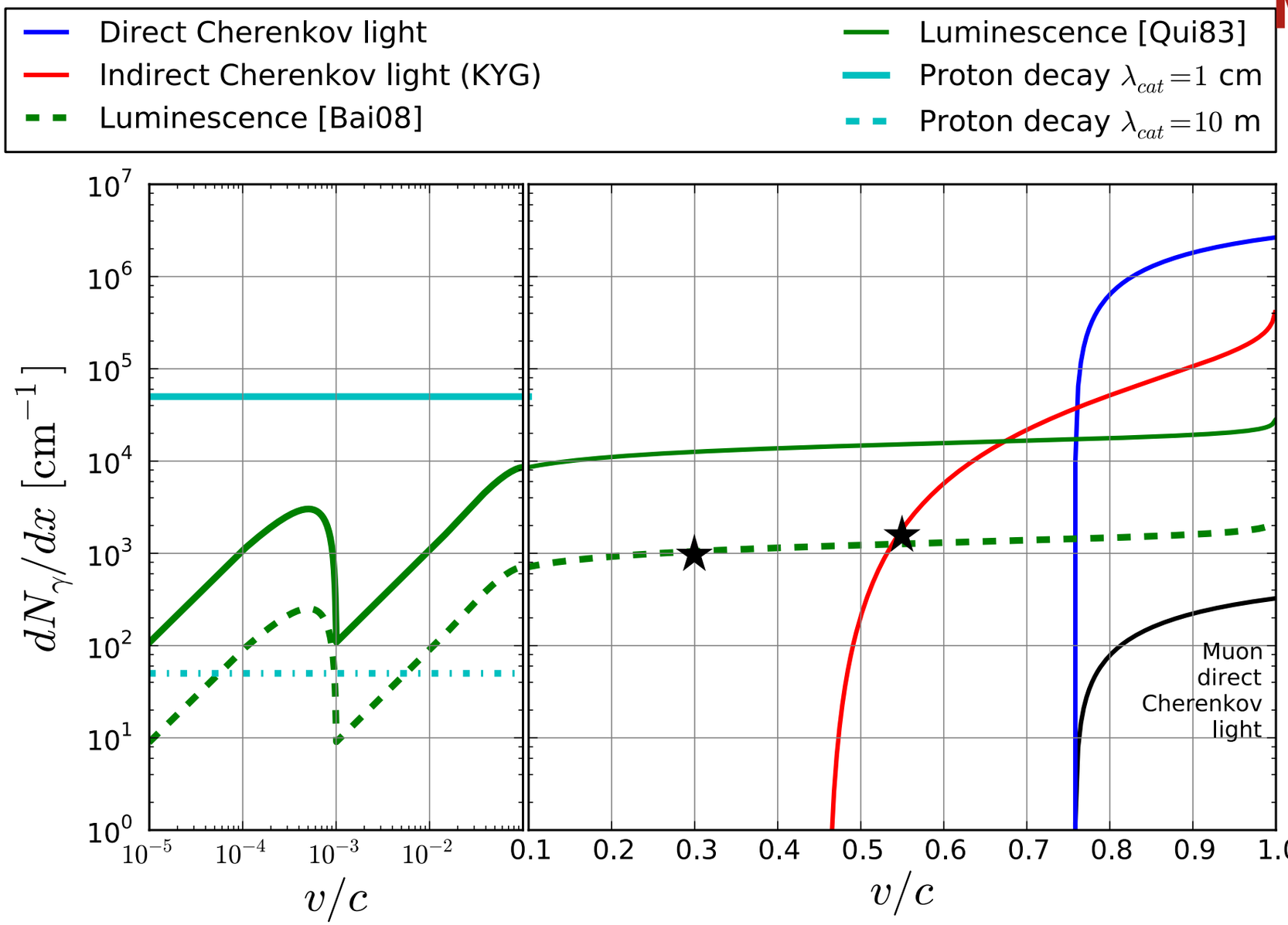
Monopole Signatures in IceCube



Light yield of Monopoles





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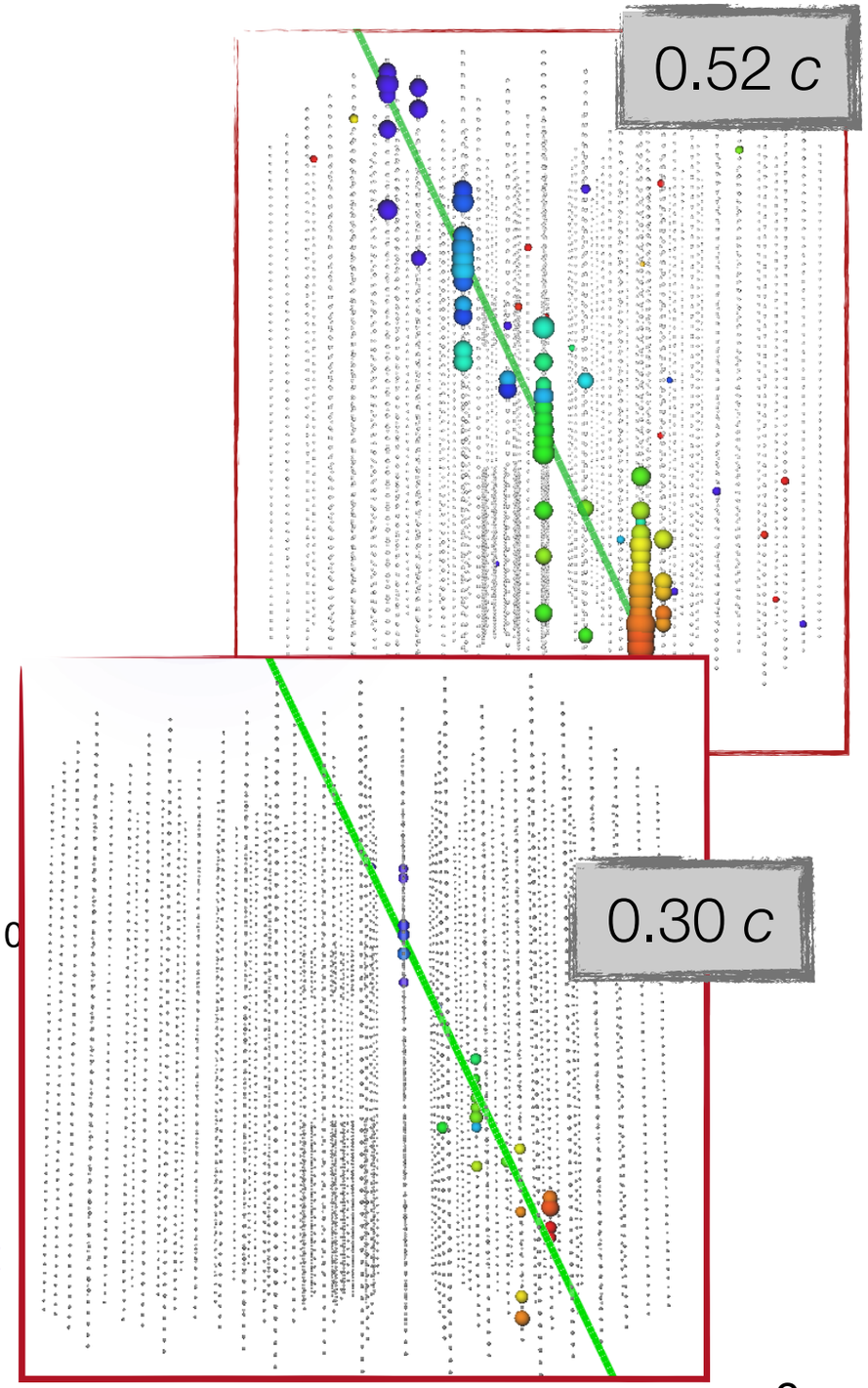
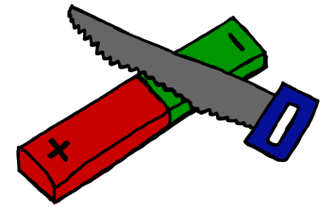


Luminescence Measurements



Measurements

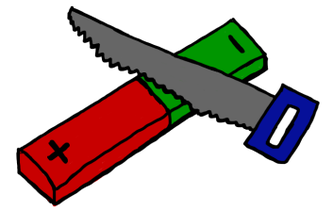
- dN_γ/dE_{dep}: luminescence efficiency
- τ: life times of excited states
- λ: wavelength spectrum

Dependencies

- temperature -50 - +20°C
- radiation type (e^-, ions, UV)
- impurities (air, surrounding materials)
- pressure

https://pixabay.com

Luminescence Measurements



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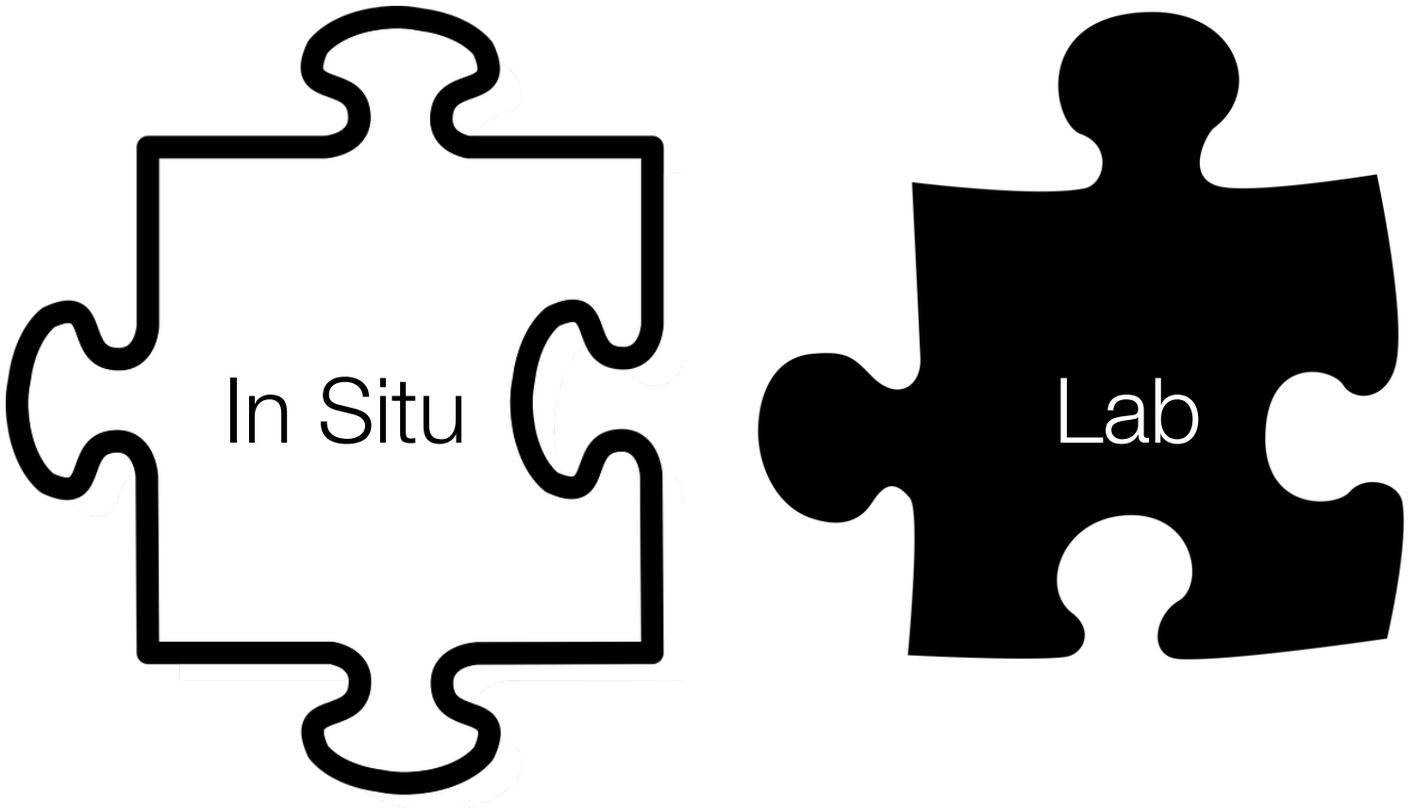
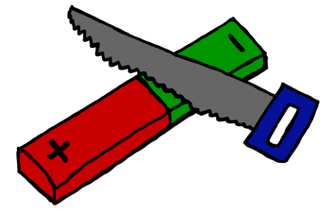
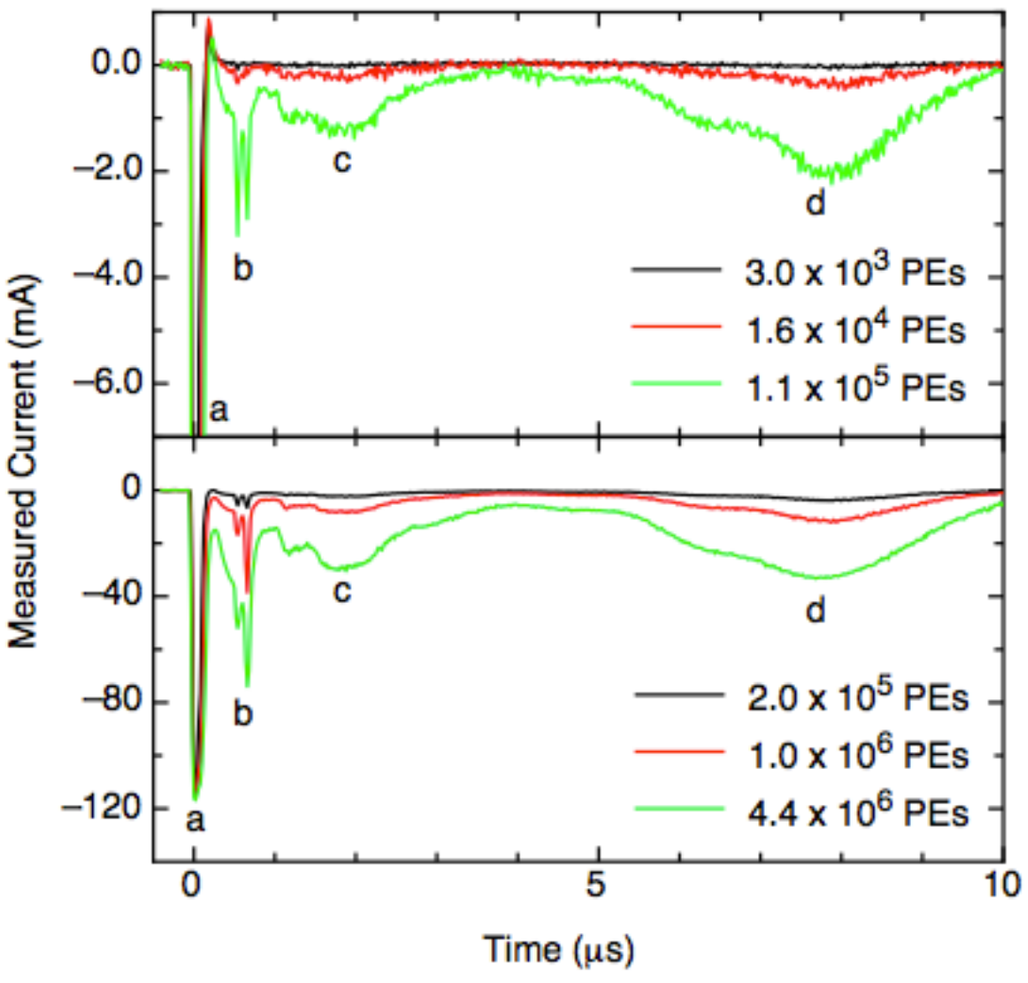


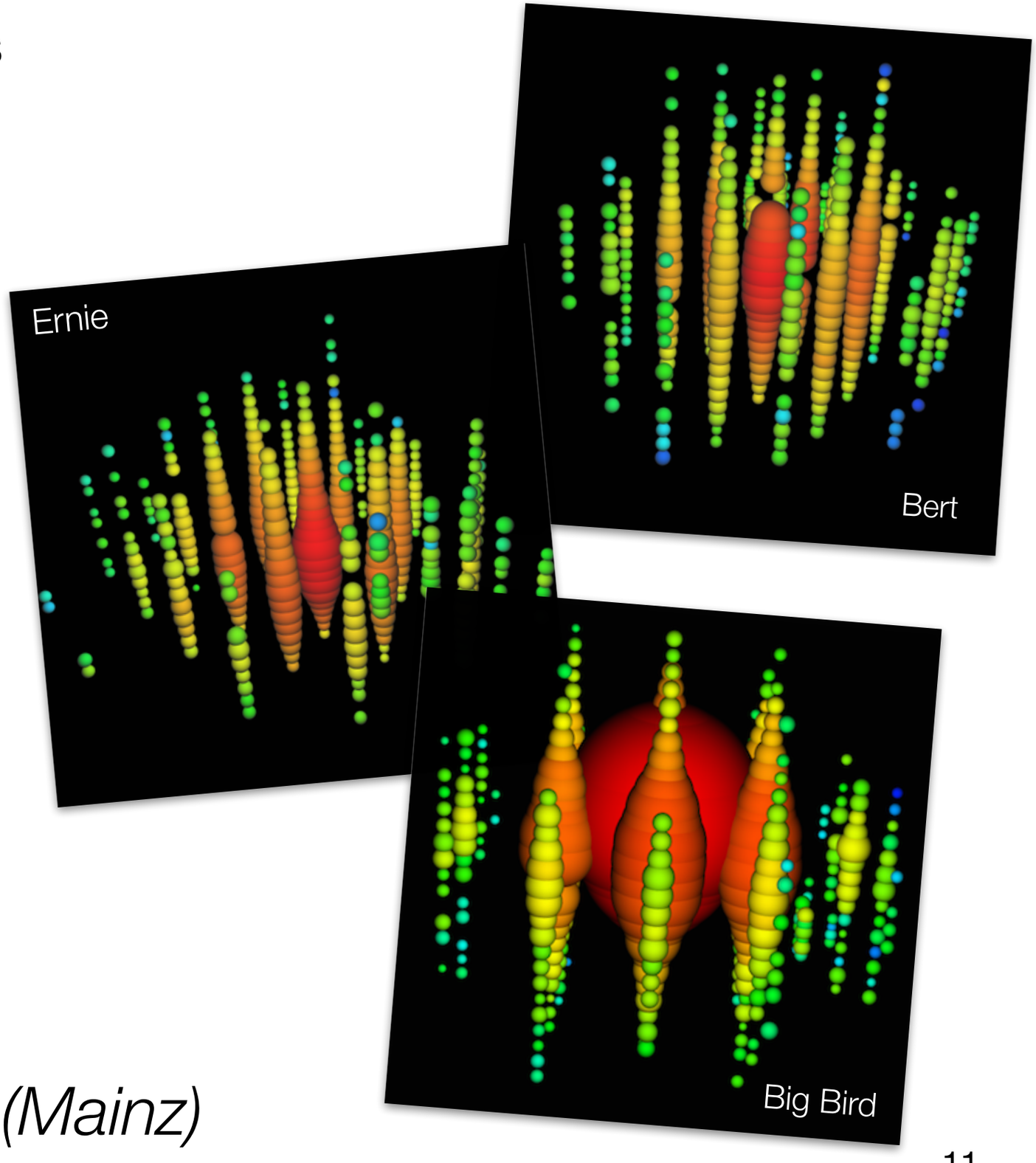
https://pixabay.com

In situ - 1



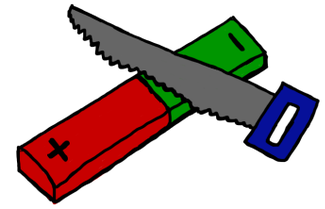
analyze late features in waveforms
near vertex of HE events





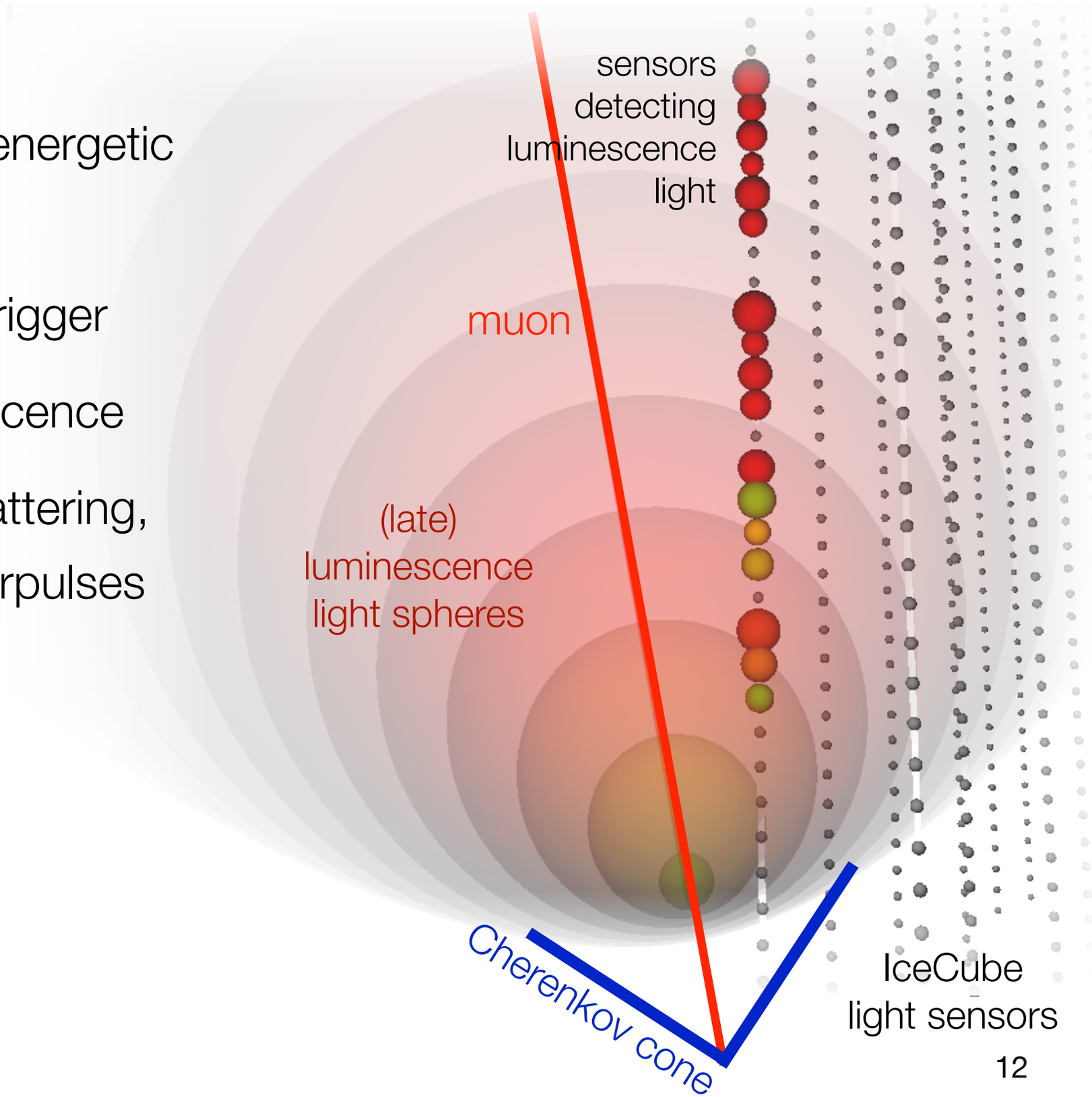
see work by Anna Steuer (Mainz)

In situ - 2

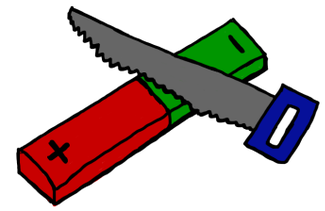


analyze waveforms of low energetic vertical muon events

- Cherenkov cone as trigger
- late hits from luminescence
- background from scattering, PMT noise, PMT afterpulses



In situ - 3

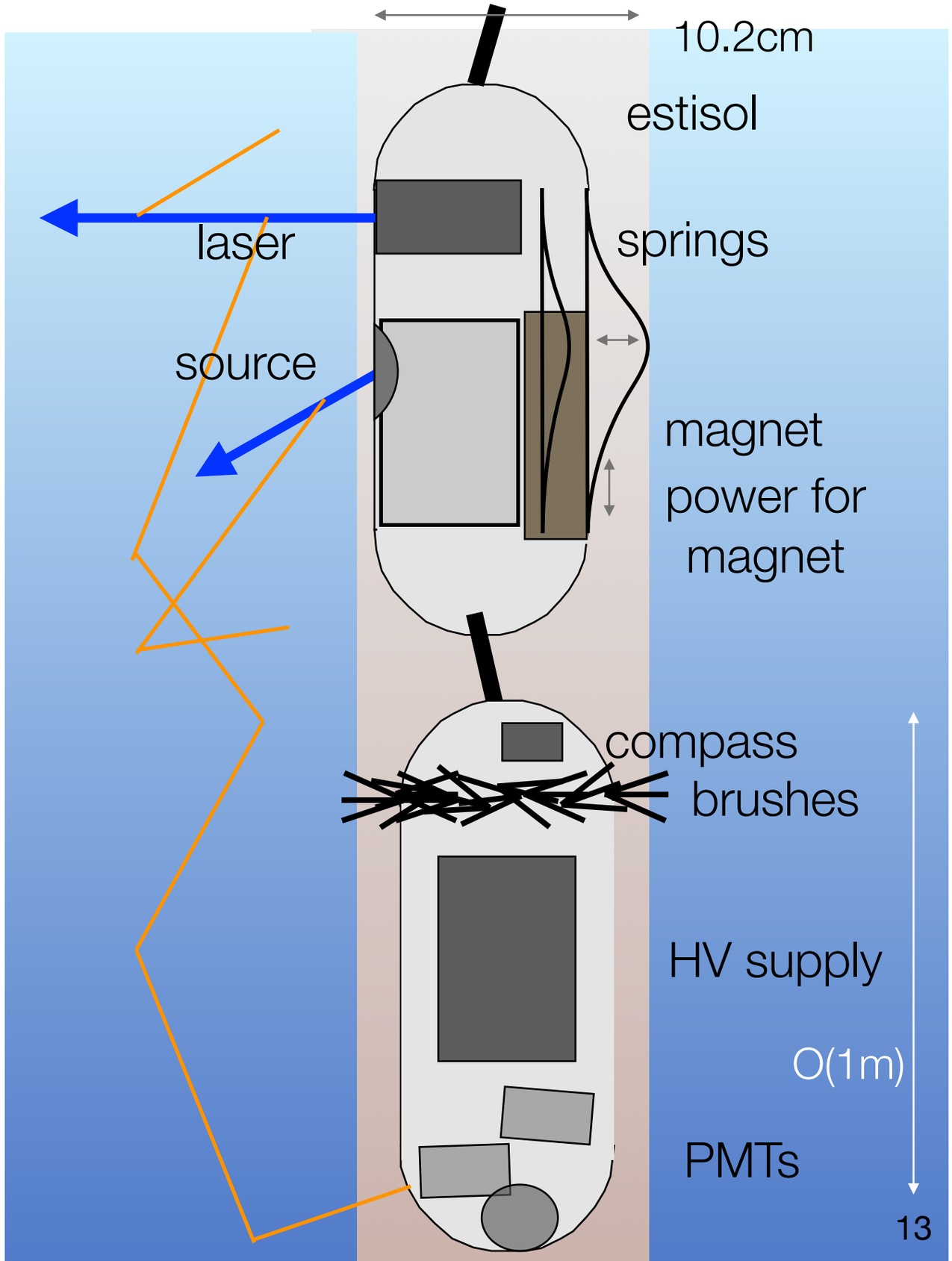


- device in open SPICE hole
- press to ice wall
- radiate the ice
- measure light

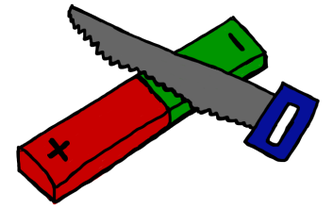
Luminescence from UV light:

Absorption:	220 nm	260 nm
Emission:	~ 340 m	~ 420 nm
Lifetime:	< 12 μs	1.6 s 4.2 s
Efficiency: d(lnI)/d(lnD)	< 1.11	1.11

Langford,Acc.Chem. Res. 2000, 33, 665-671

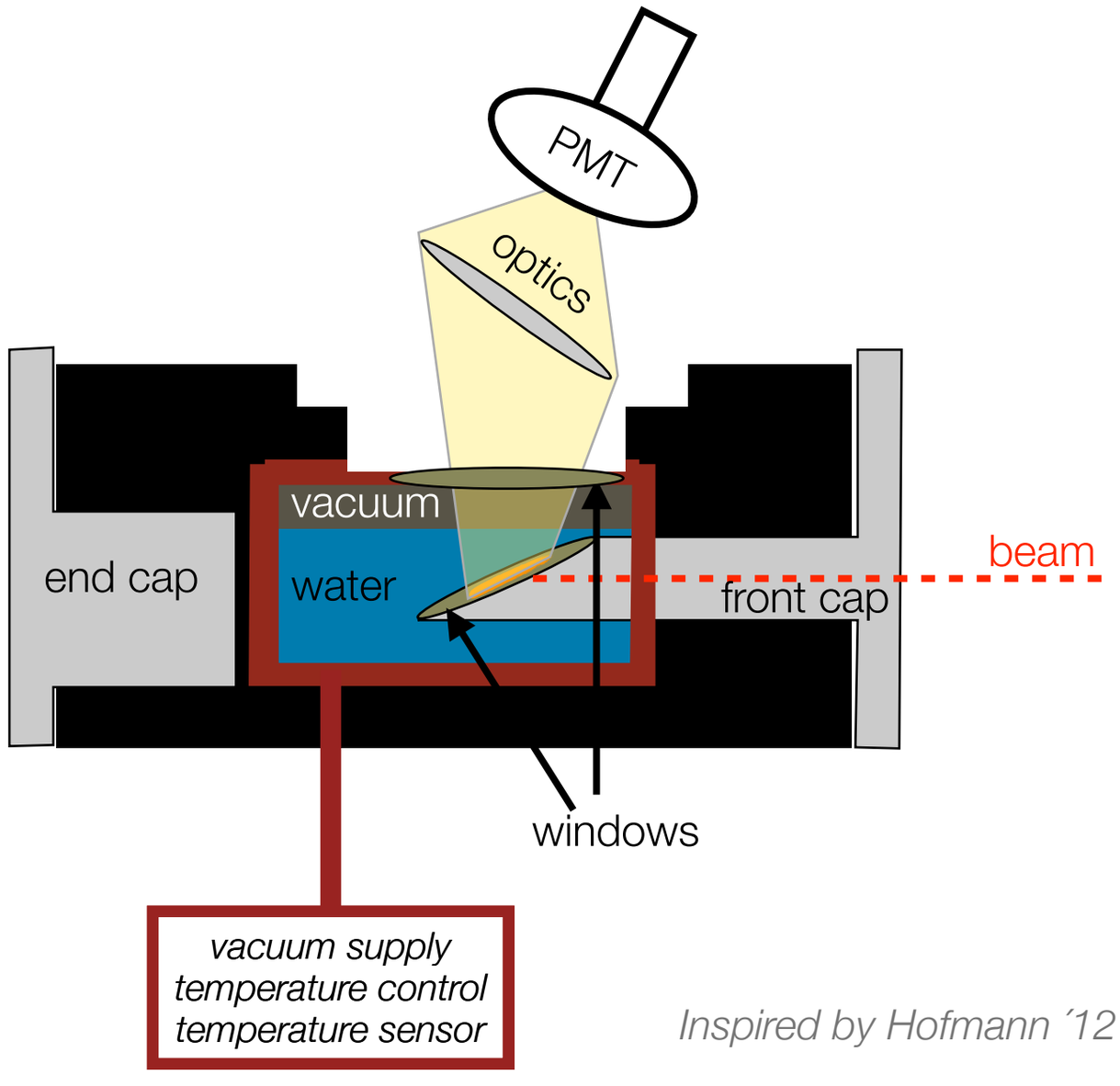


Laboratory measurements



Final goal:

- water / ice sample from detector sites
- Z=68e charged and heavy ions
- accelerated to speeds below the Cherenkov threshold

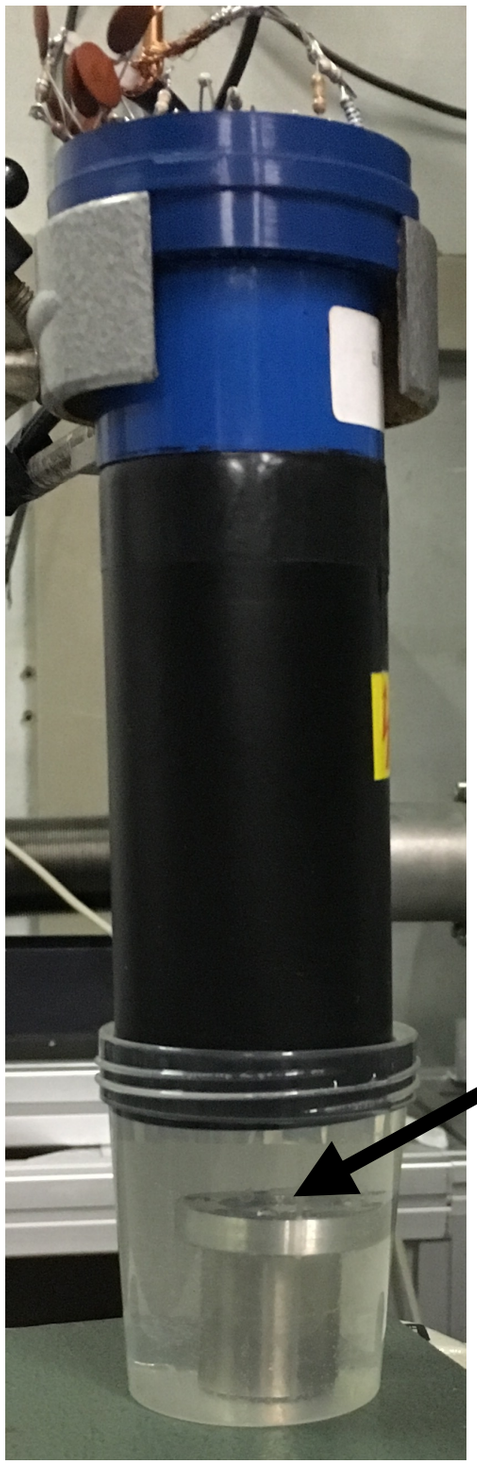


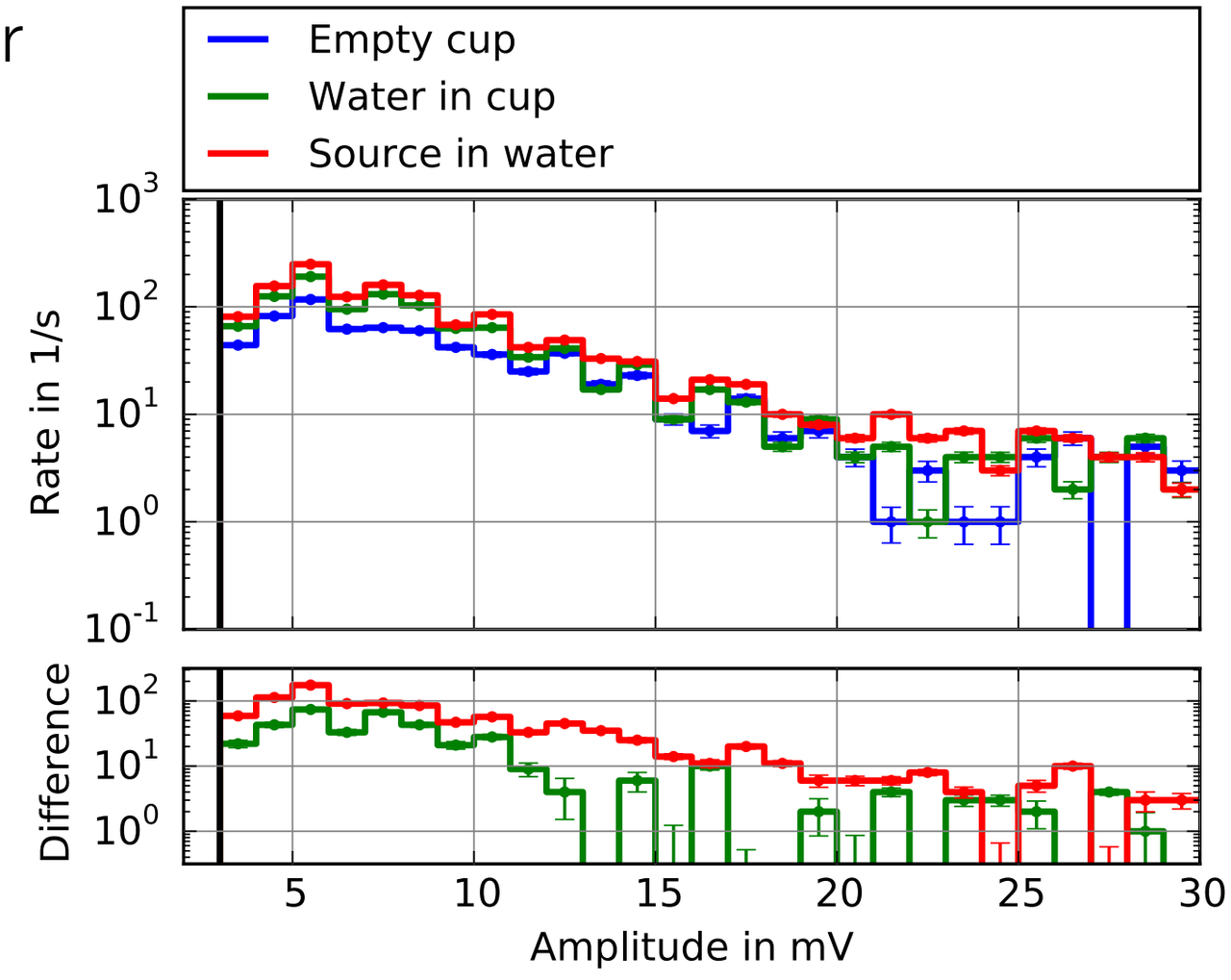
Inspired by Hofmann ´12

Setup of first measurement

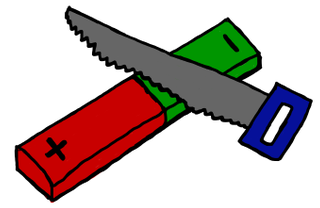
started with a simple setup at room temperature:

- ^{241}AM α source with activity ~1.7 MBq
  - ➡ soft γ-ray: 33-160 keV
  - ➡ 700-9000 photons / sec from luminescence expected
- photomultiplier
- drinking water



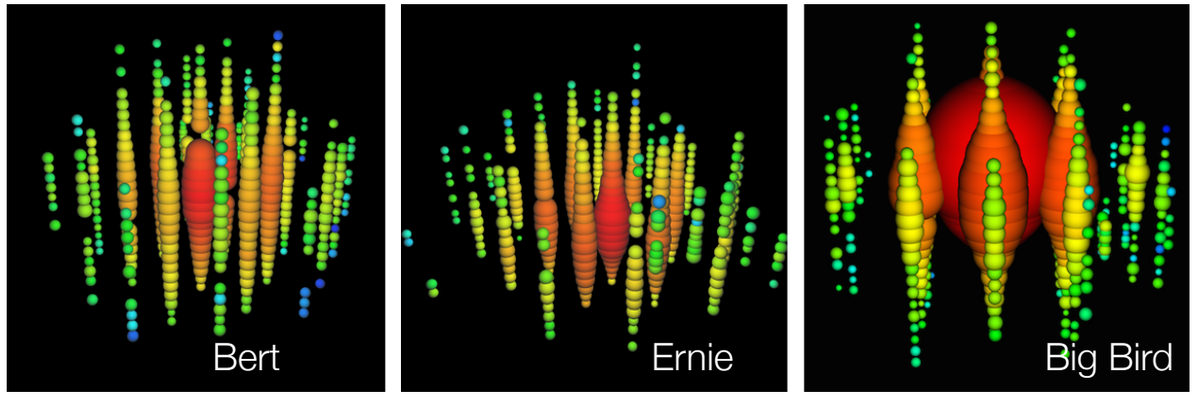


Further Applications



- Magnetic monopoles
  - non-relativistic < 0.1 c
  - low relativistic > 0.1c

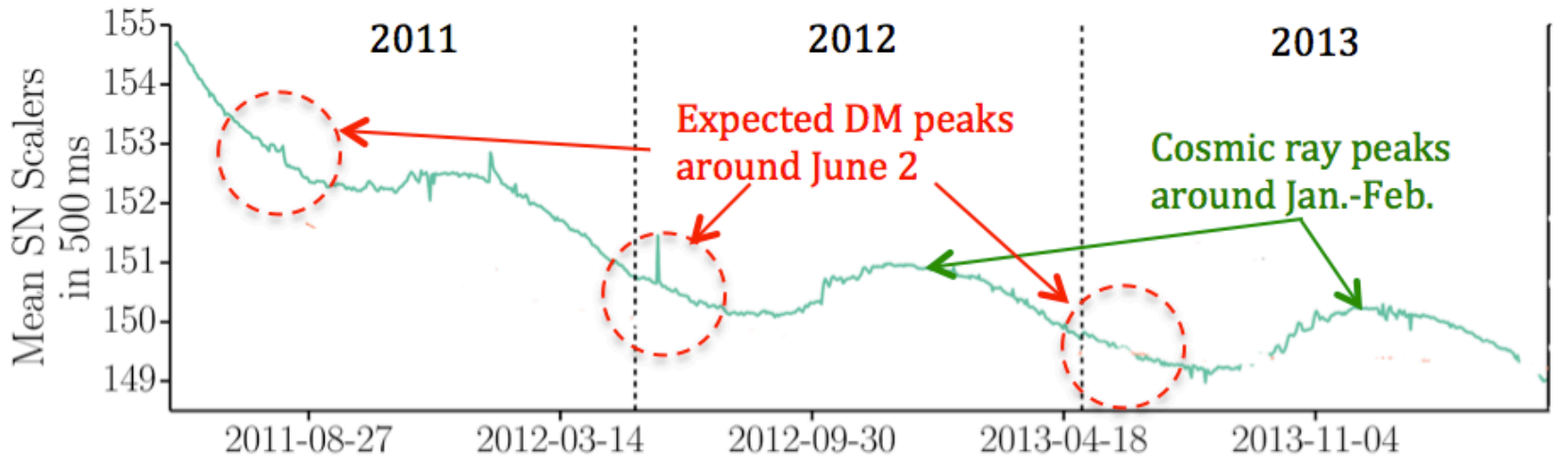
- improving energy reconstruction



- correlated noise on very long time scales (milliseconds)

- dark matter annual modulation

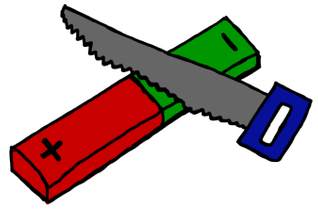
- neutral exotic particles



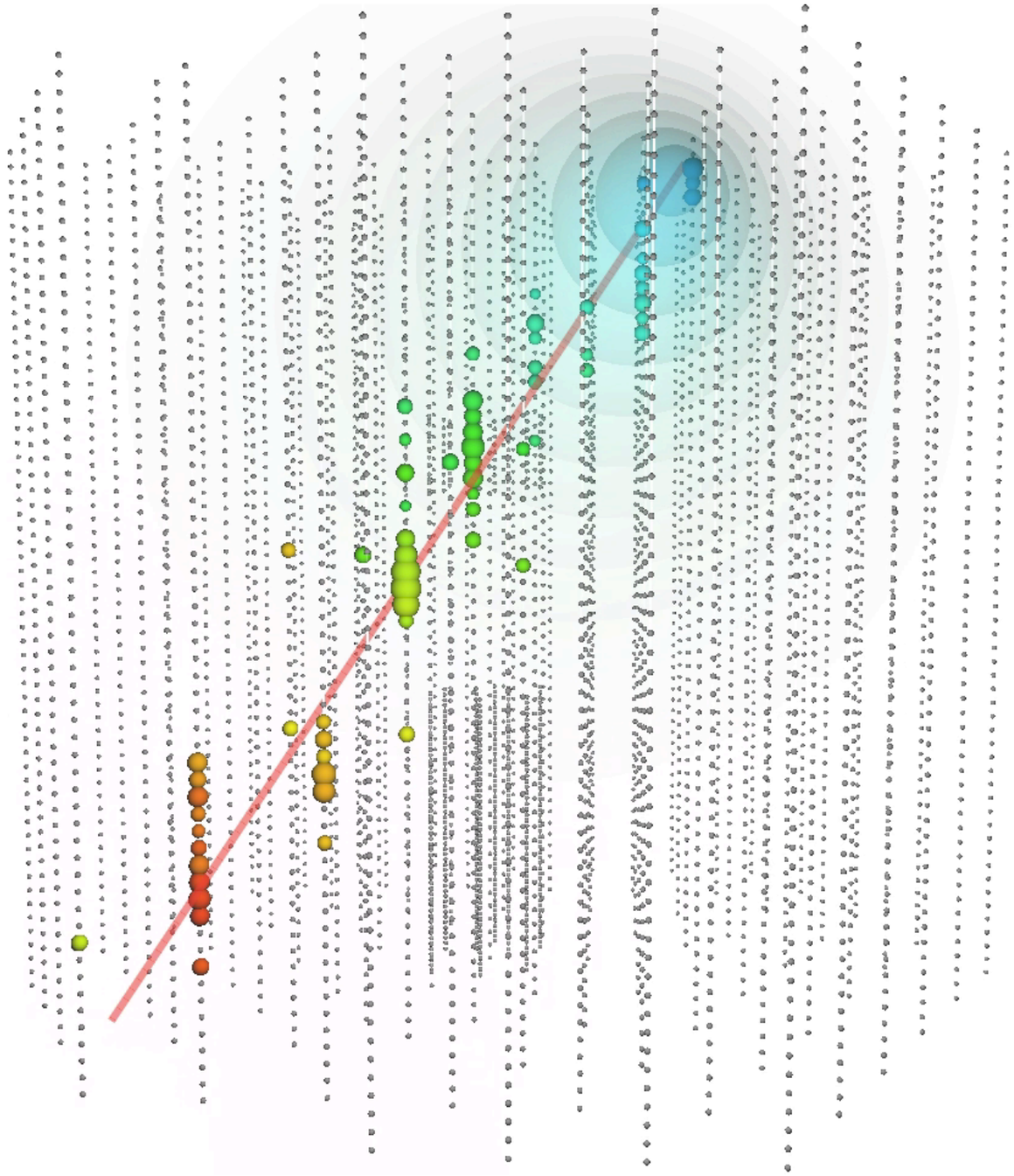
Idea by Jerry Vavra / Stanford

analysis in the group of Kael Hanson

Conclusion



- luminescence extends detection possibilities of water-Cherenkov telescopes
- started lab measurements
- started monopole search



Other efforts in monopole searches at IceCube:

- non-relativistic using proton decay signature
- high relativistic using direct Cherenkov light