November, 2018, The Netherlands

KM3NeT hydrophones for relic neutrino detection

Rasa Muller

PhD student at Nikhef, Amsterdam

Previous intern at TNO Delft

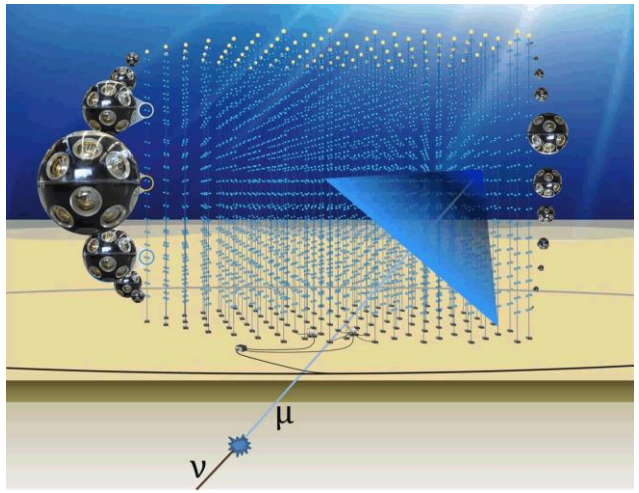
Contributions

Ernst-Jan Buis – Ivo van Vulpen

November, 2018, The Netherlands

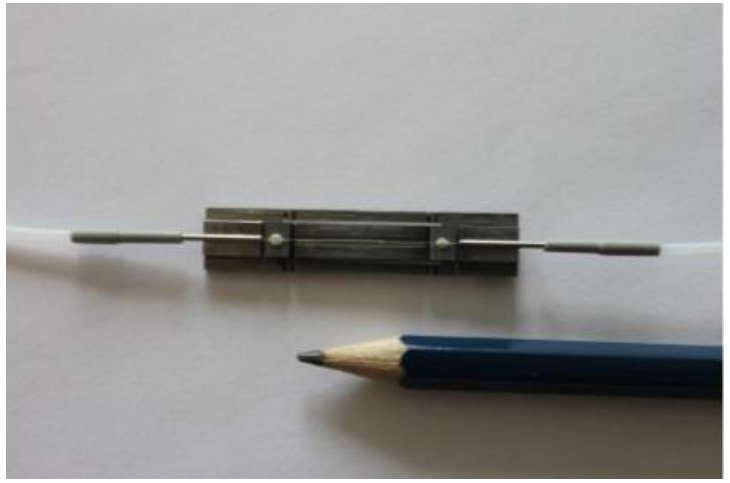
Km^3
Neutrino
Telescope

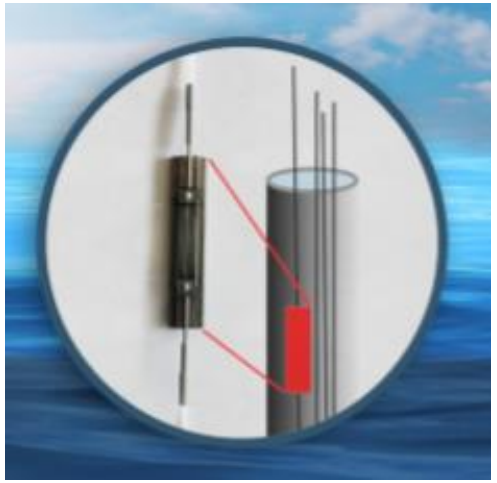
KM3NeT hydrophones for relic neutrino detection



KM3NeT hydrophones for relic neutrino detection

Microphones underwater





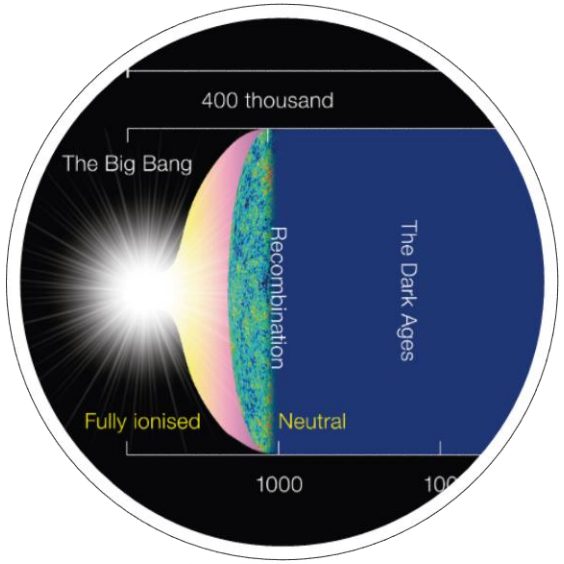
Optical fiber

Piezo

KM3NeT hydrophones for relic neutrino detection

Cosmological neutrino

Cosmic Neutrino Background ($C\nu B$)



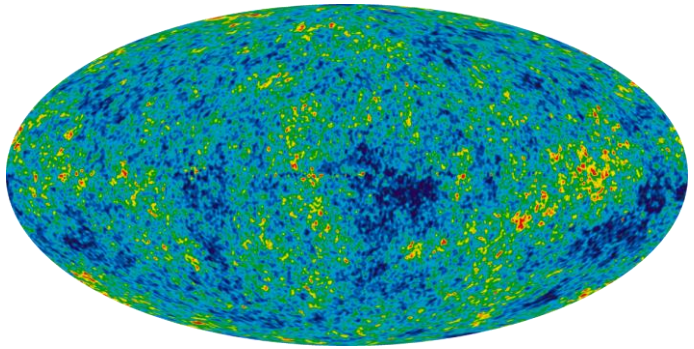
CνB is closely related to CMB

CMB

- Cosmic microwave background
- Due to expansion of universe past 13.8 billion year history: 2.725 K

CνB

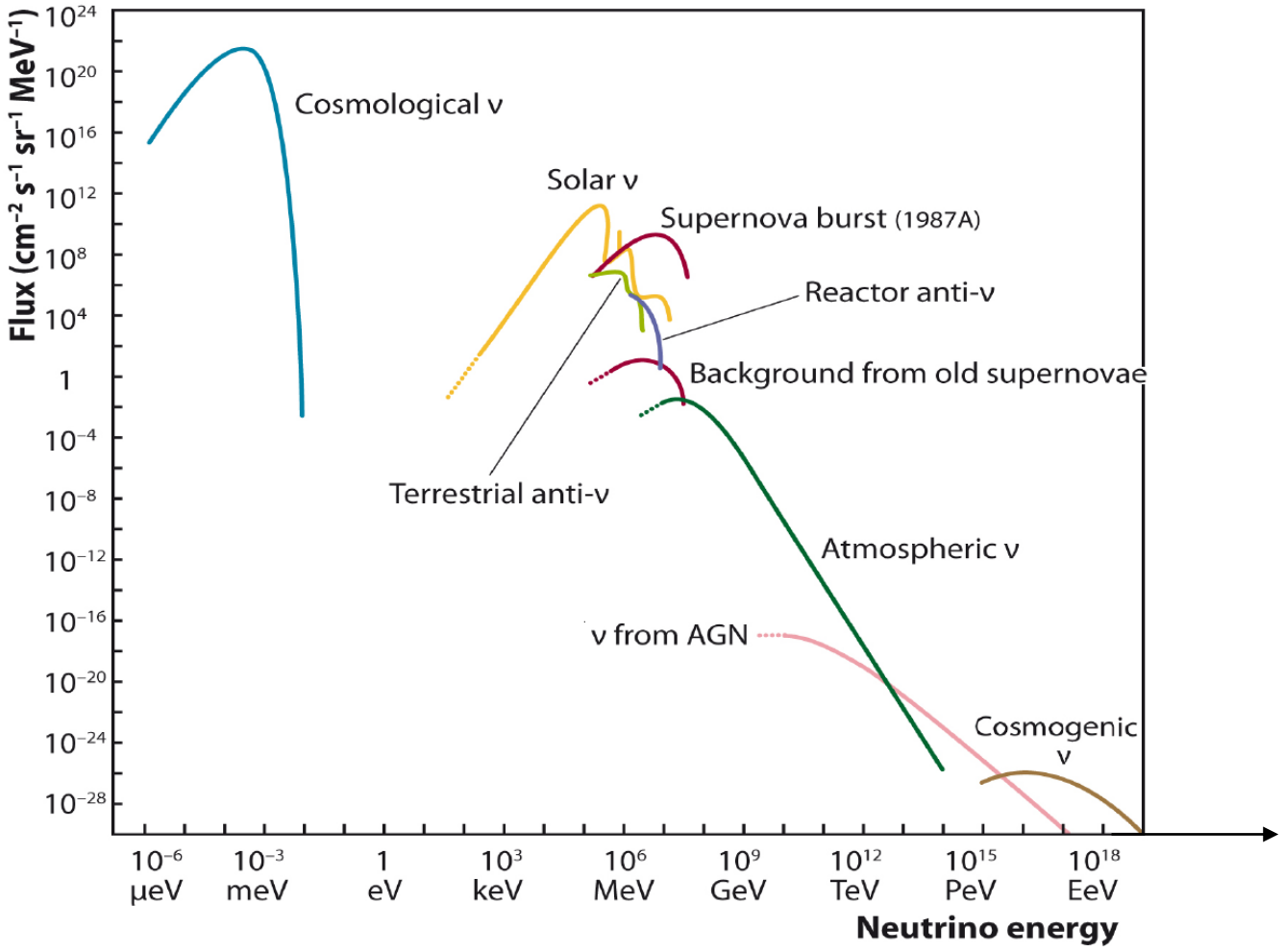
- Cosmic neutrino background
- $\left(\frac{4}{11}\right)^{1/3}$ of the CMB temp: 1.95 K



<u>Energy per particle</u>

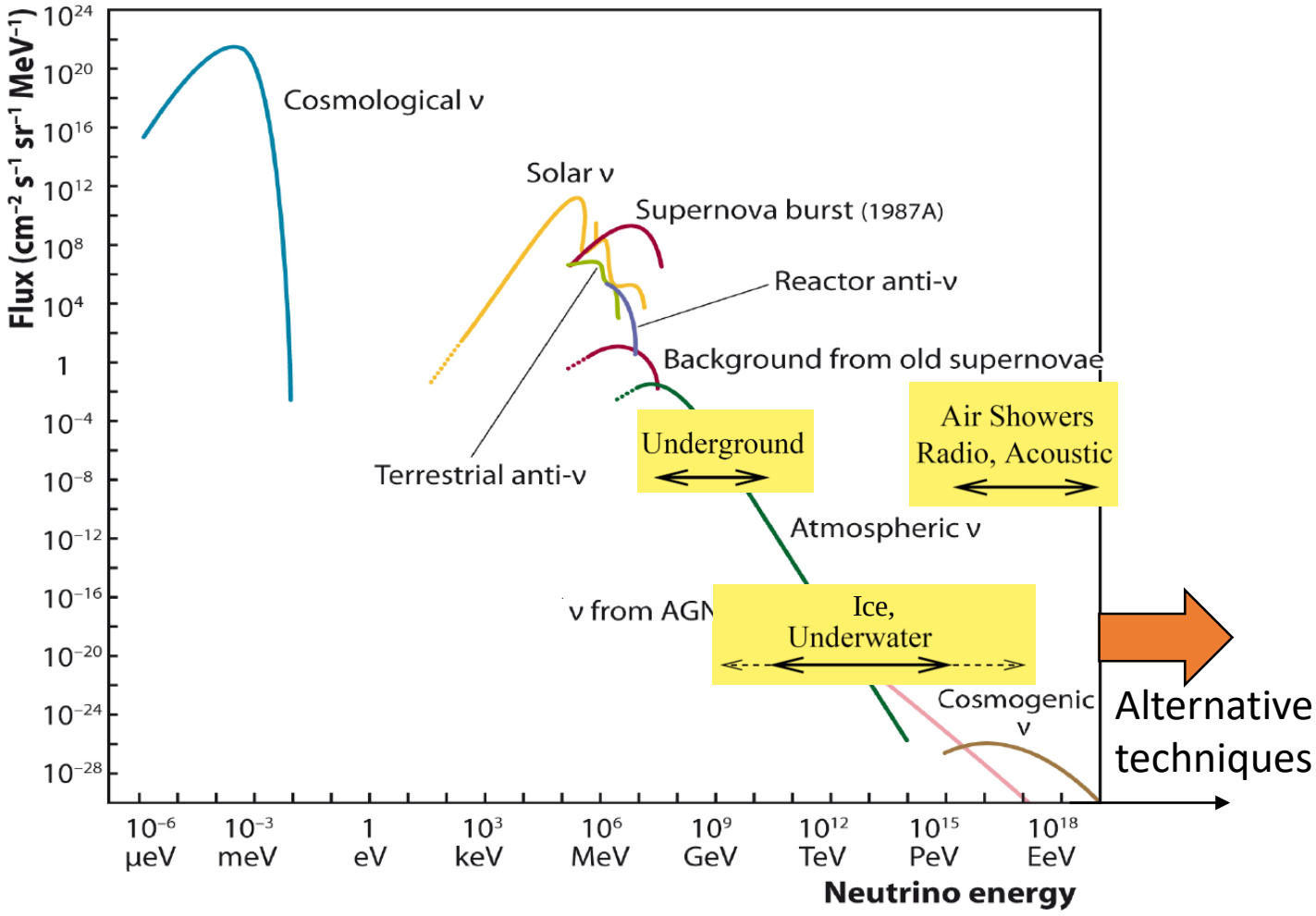
μeV - meV range

Neutrino's exist in a wide E-range

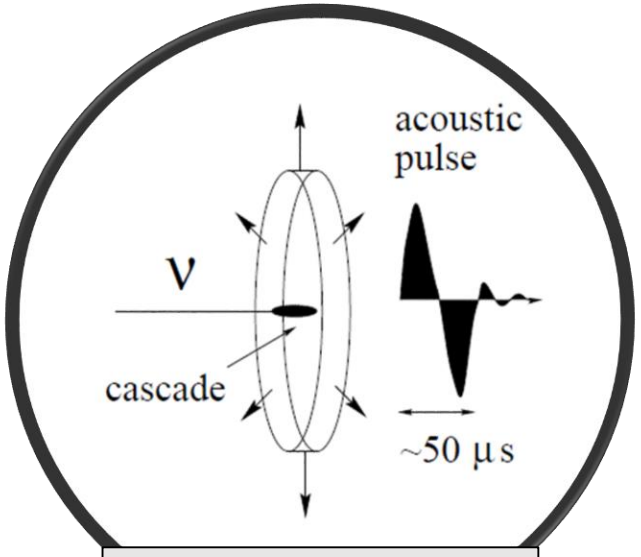


U.F. Katz, Ch. Spiering 2011:
High-Energy Neutrino Astrophysics: Status and Perspectives

Large variety to detect neutrino's



Alternative techniques



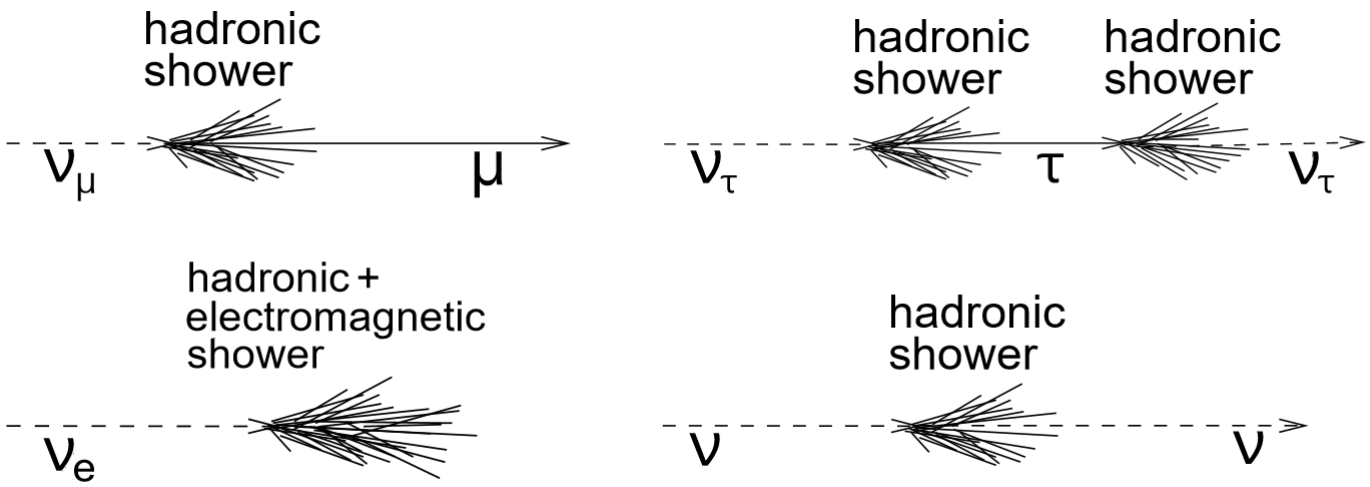
E_ν ~ 10^{14} eV → nPa
E_ν ~ 10^{21} eV → Pa

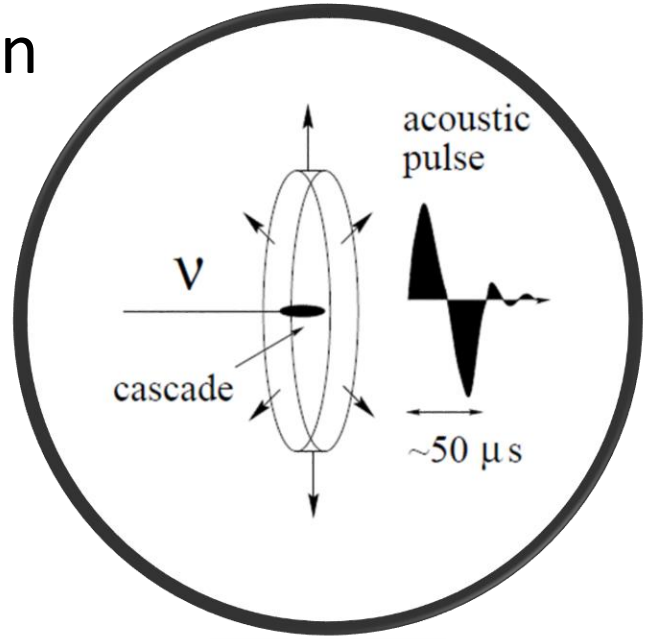
Acoustics!

U.F. Katz, Ch. Spiering 2011:
High-Energy Neutrino Astrophysics: Status and Perspectives

Acoustic neutrino detection

- Rapid expansion of medium after energy deposition and subsequent heating
- Expansion leads to a pressure wave in water

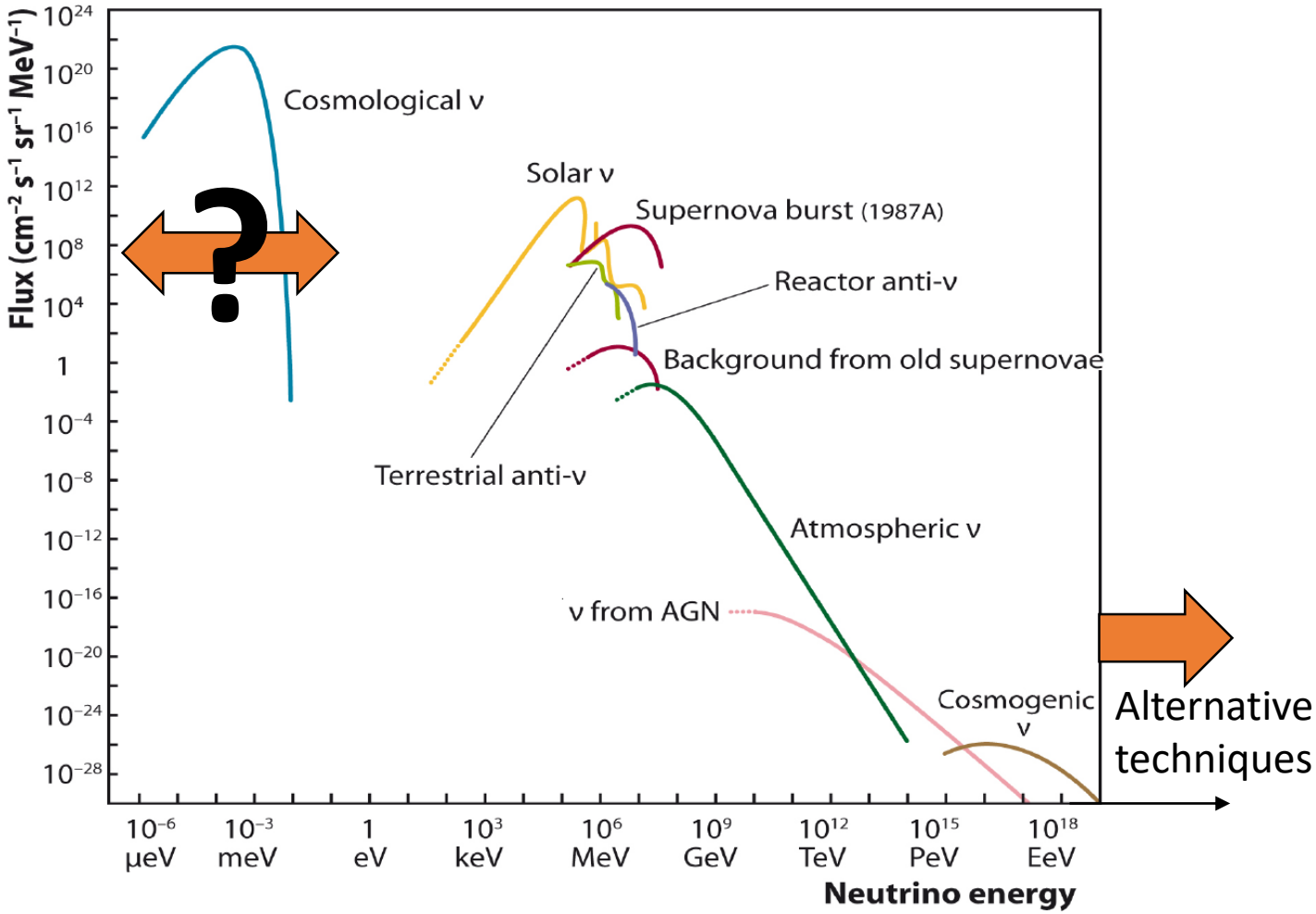




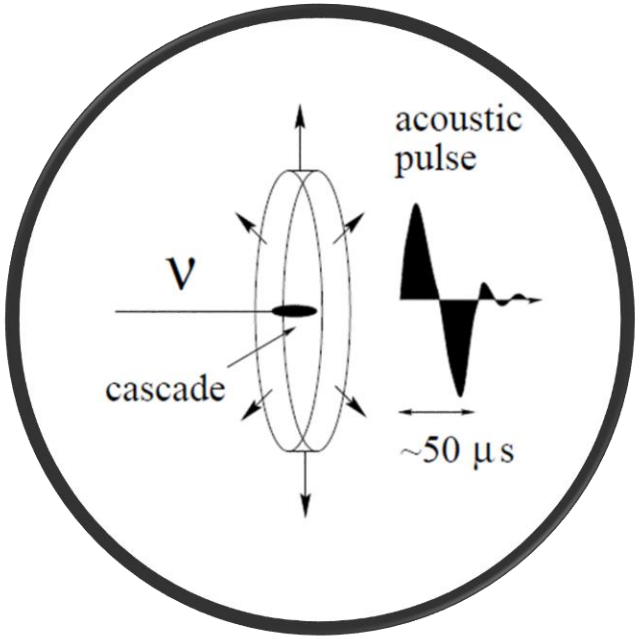
Acoustics!

G.A. Askariyan, et al., 1979:
Acoustic detection of high energy particle showers in warer

Method to detect cosmic neutrino's



Alternative techniques



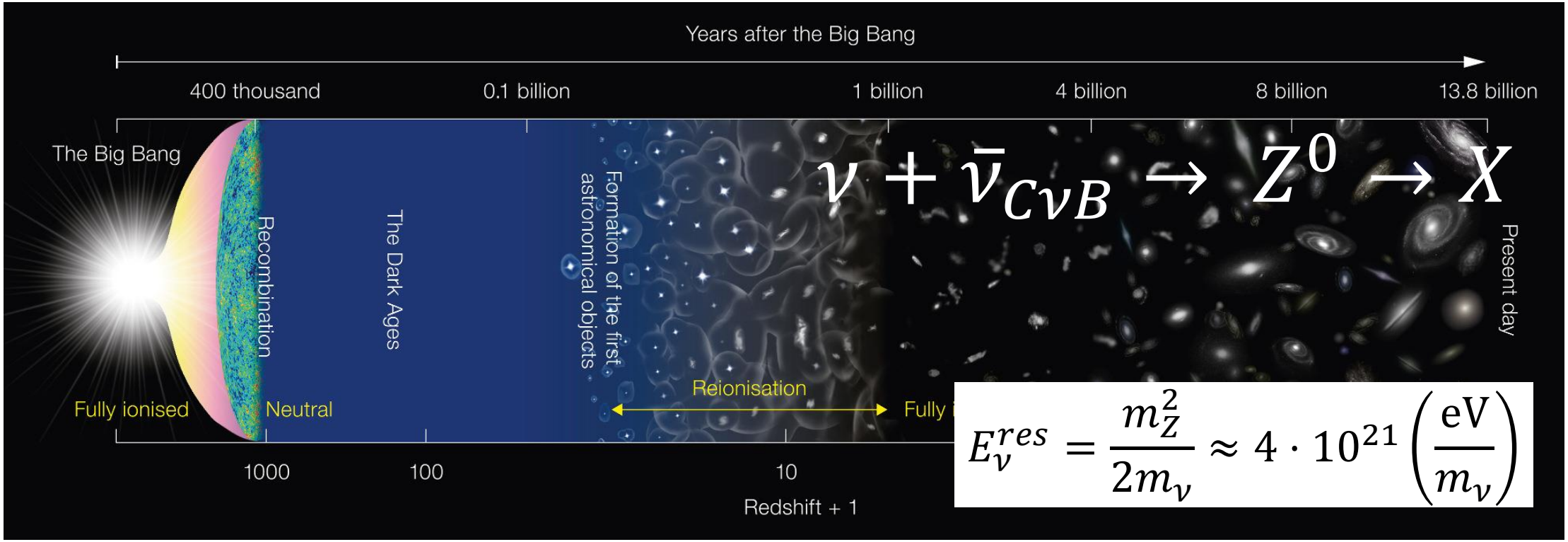
Acoustics!

U.F. Katz, Ch. Spiering 2011:
High-Energy Neutrino Astrophysics: Status and Perspectives

Relic neutrinos

If relic ν's exist:

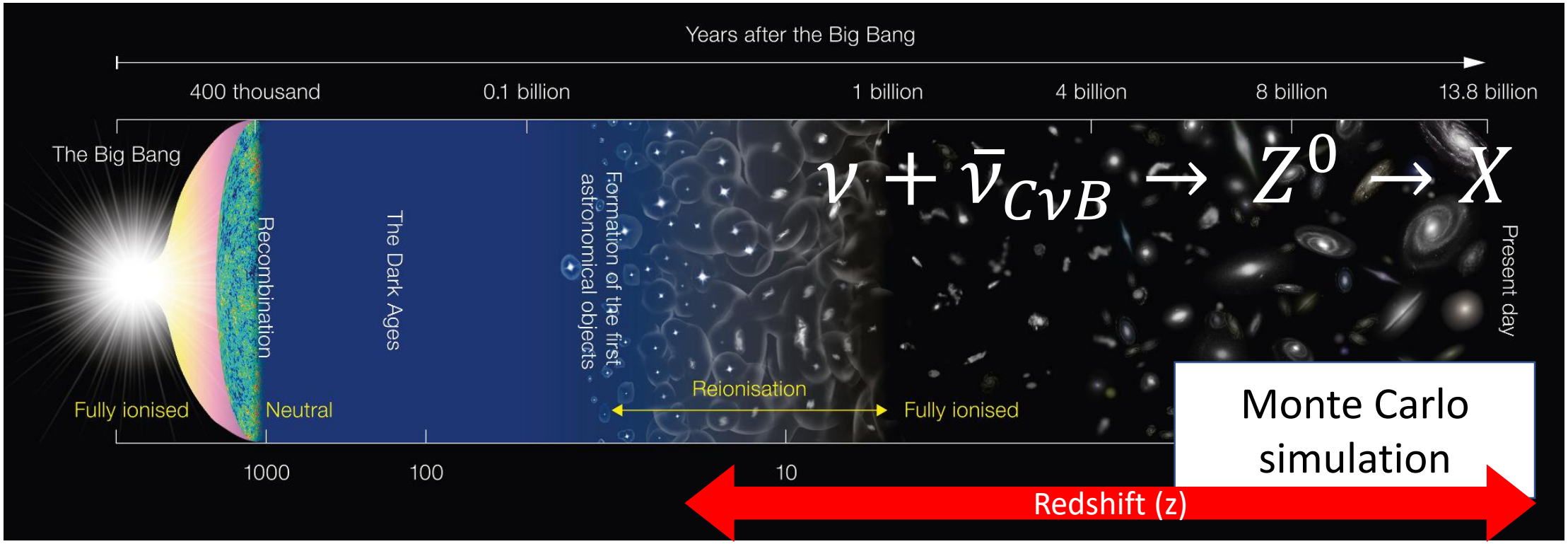
Extremely high E ν's get absorbed at the Z-resonance by the CνB



KM3NeT hydrophone network to detect relic neutrinos

How many acoustic detections EHECν in what E-range are required to prove the existence of relic neutrinos?

Relic neutrinos



$$\nu + \bar{\nu}_{C\nu B} \rightarrow Z^0 \rightarrow X$$

High energy sources are required

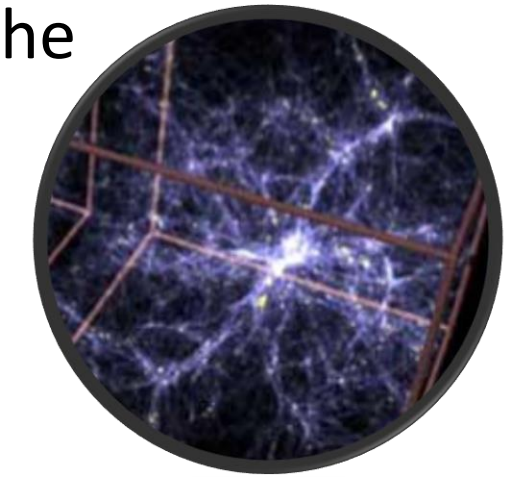
Bottom up

- Sources capable of extreme "acceleration" (galactic)

- z ~ 2
- GRB / AGN

Top down

- High energy particles were "born" with these energies (physics beyond the standard model)



- z ~ 20
- super heavy dark matter decay

Expected flux at Earth

Primary Flux

1. Survival Probability $P(E(1+z), z)$
   Chance of a cosmic neutrino *(injected at redshift z with energy E)* ***to survive on its way to Earth***

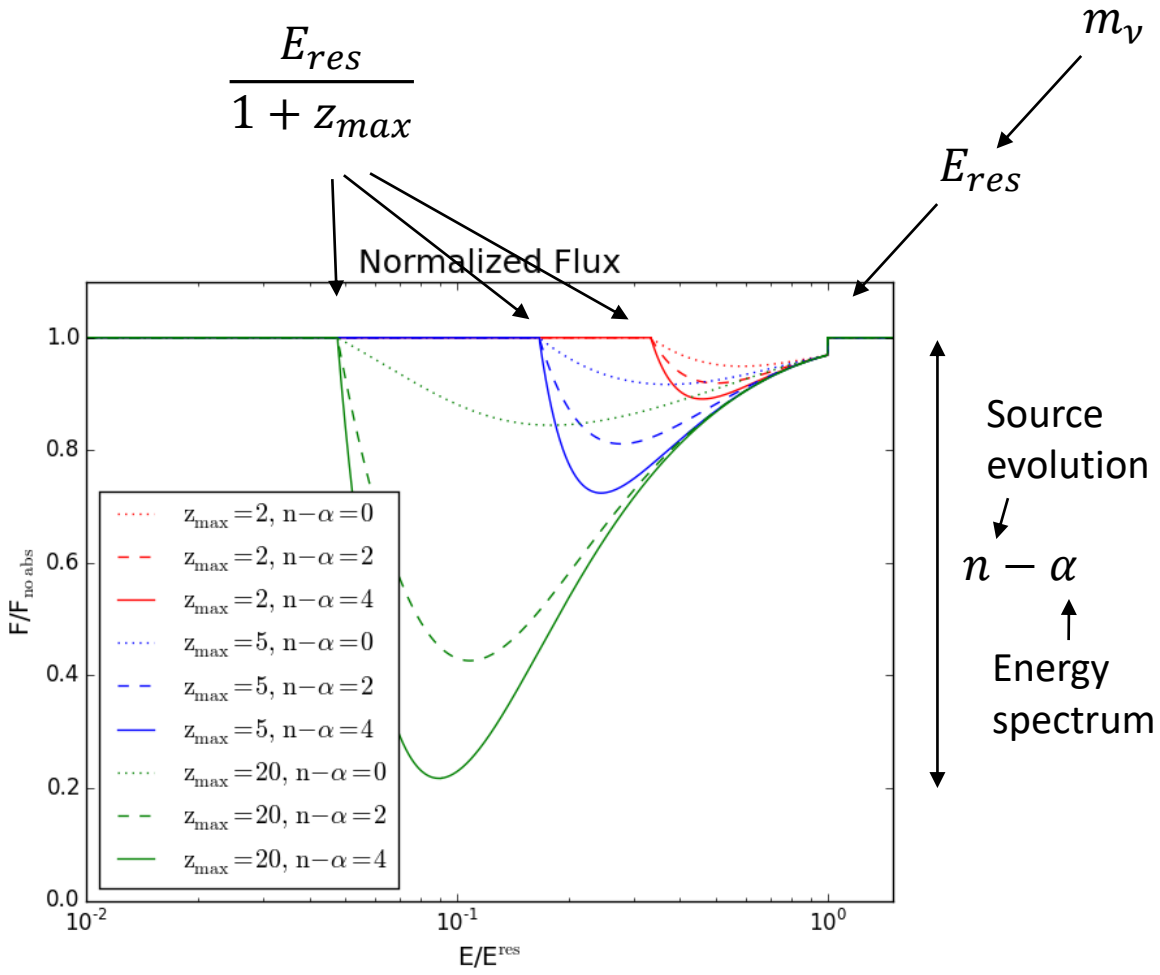
2. Source emissivity $L(E(1+z), z)$
   Number of neutrinos *(per flavor and Energy)* ***emitted per comoving volume***

Expected flux at Earth

Primary Flux

1. Survival Probability *P(E(1+z), z)*
   Chance of a cosmic neutrino *(injected at redshift z with energy E)* ***to survive on its way to Earth***

2. Source emissivity *L(E(1+z), z)*
   Number of neutrinos *(per flavor and Energy)* ***emitted per comoving volume***



Expected flux at Earth

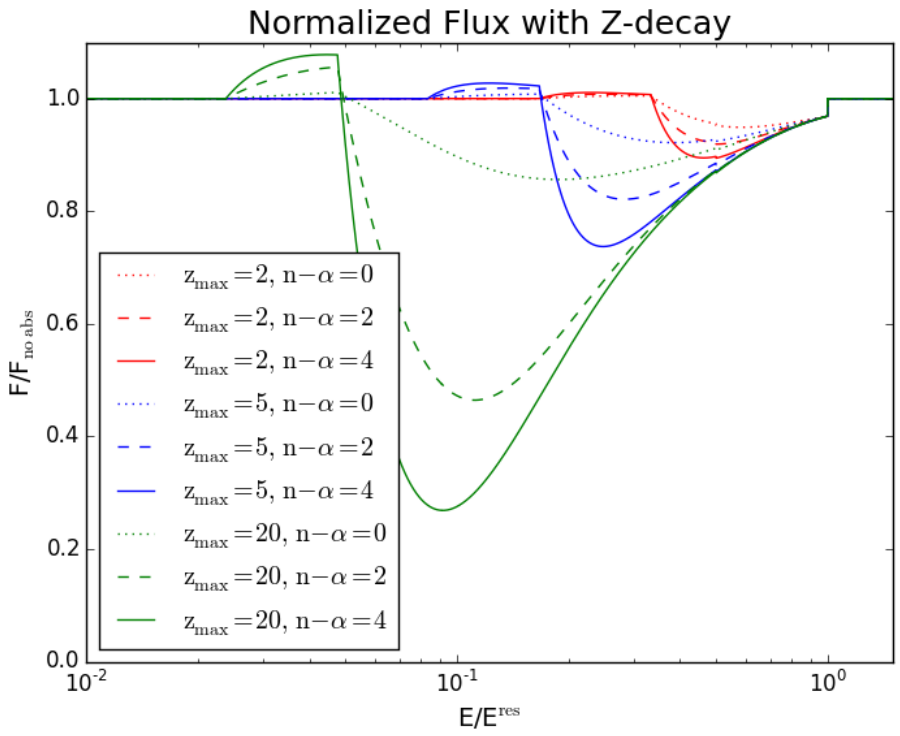
Primary Flux

1. Survival Probability *P(E(1+z), z)*
   Chance of a cosmic neutrino *(injected at redshift z with energy E)* ***to survive on its way to Earth***

2. Source emissivity *L(E(1+z), z)*
   Number of neutrinos *(per flavor and Energy)* ***emitted per comoving volume***

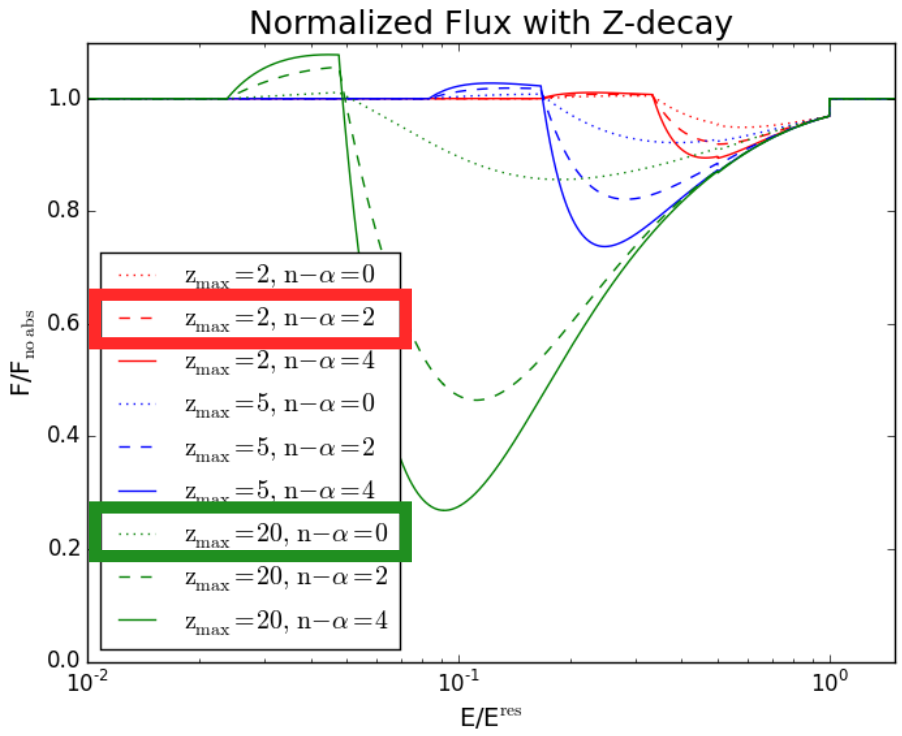
Secondary flux

$$\nu + \bar{\nu}_{C\nu B} \rightarrow Z^0 \rightarrow X$$

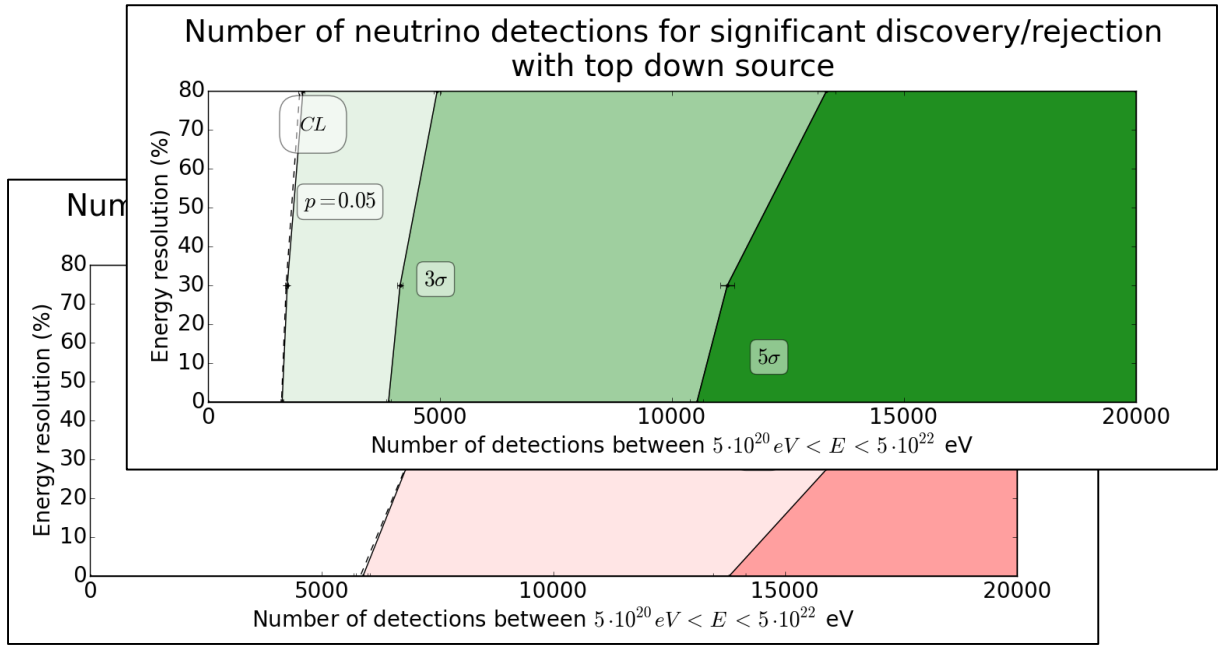


Top down and Bottom up results

Theoretical flux

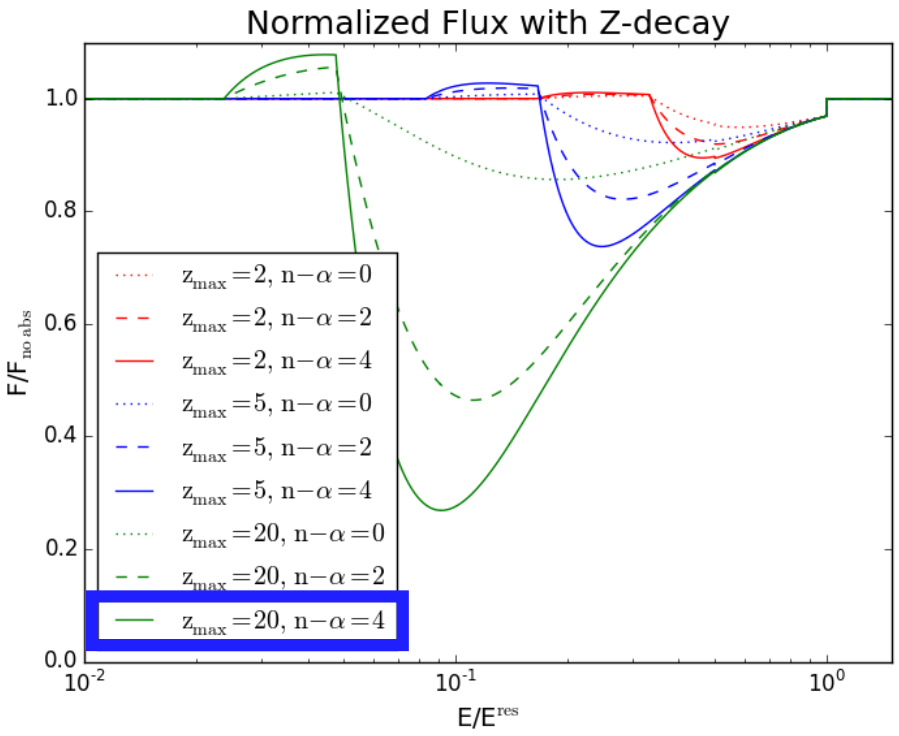


Results

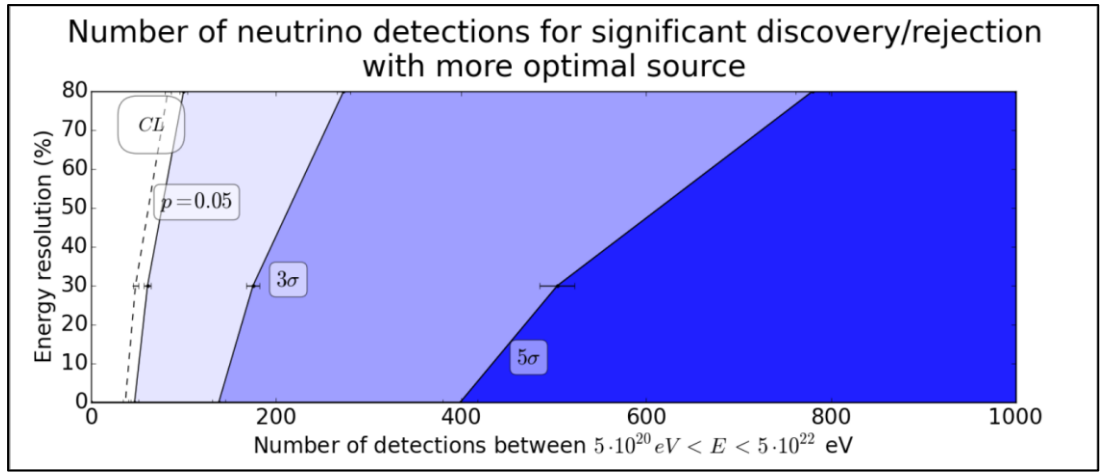


More optimal scenario

Theoretical flux



Results



Observations and Conclusions

- Type of source of major importance compared to Energy resolution of telescope
- Significant detection of TD & BU require large sample of events
- Optimal scenario factor 10 less detections required
  - Large source evolution enhances signal
- Prove of CvB not straightforward, but once detected: wealth of information on particle, astrophysical & cosmological physics

Remember:

- It is a really new part of physics!
  - Unknown *absolute* flux of extremely high energetic neutrinos
  - So far no one dared to give exact characteristics about the possible sources
    - Top Down & Bottom up
- All we need is time (and a nice hydrophone network)
- Don’t forget the additional science…

… other applications!

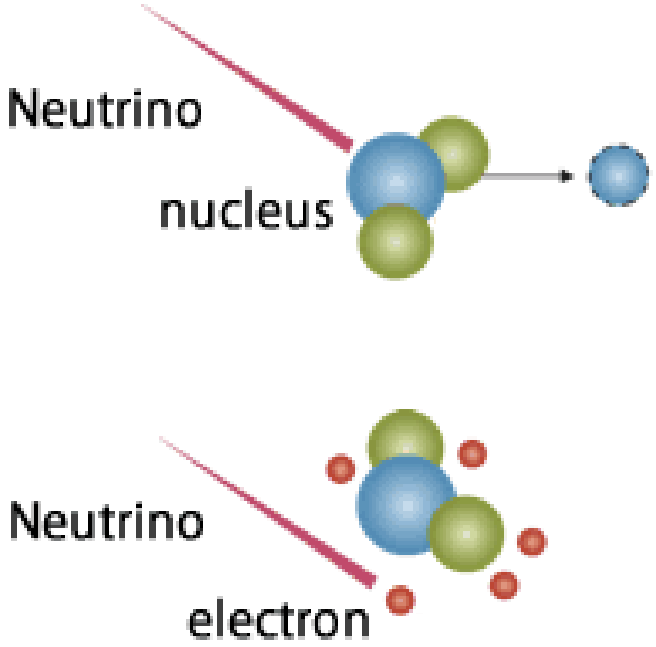
Sea life communication

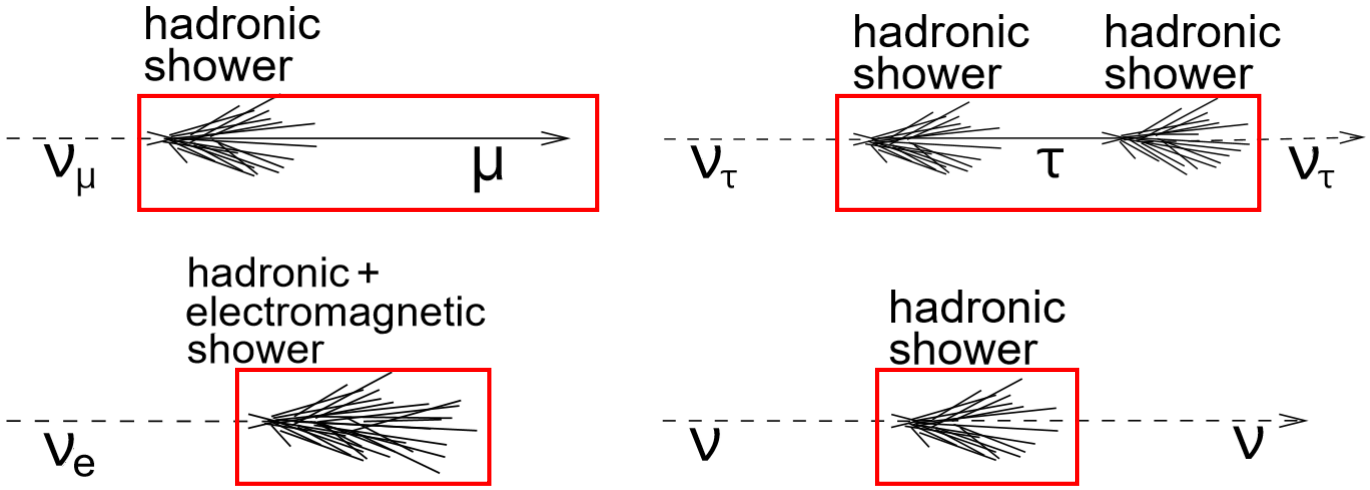
Earthquake detection

Thank you

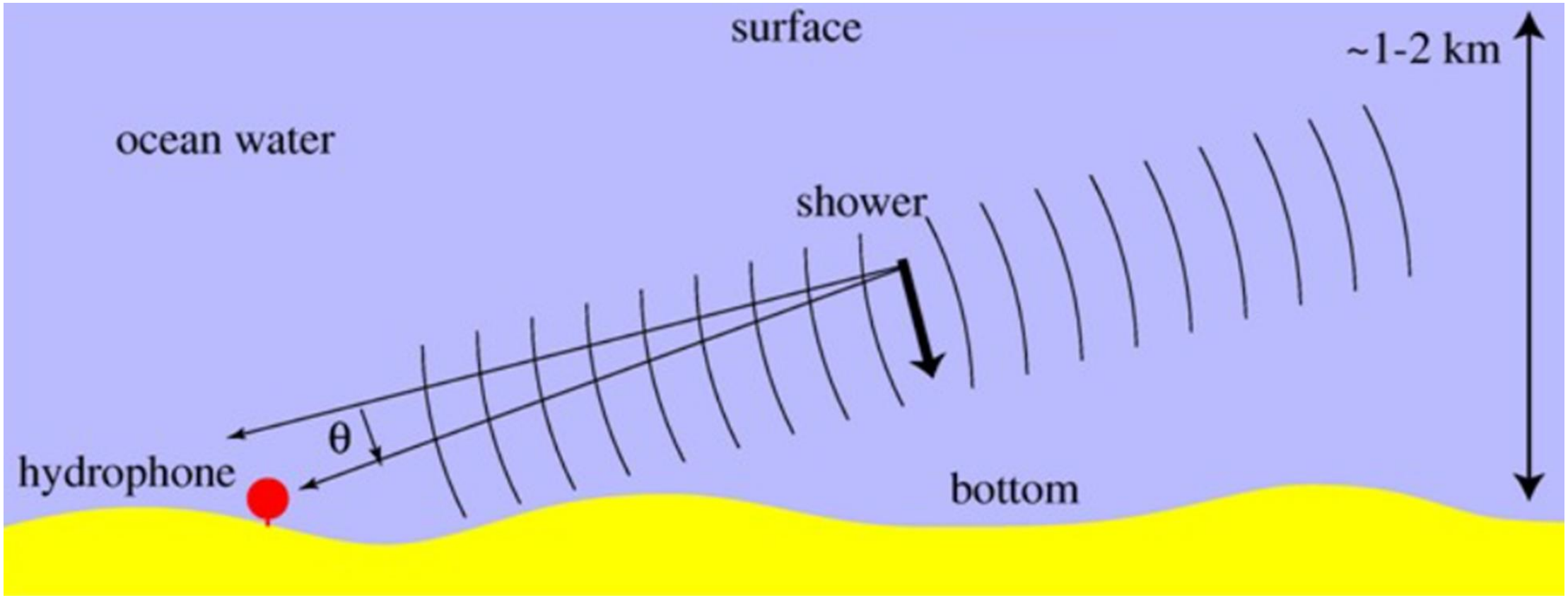
Back-up Slides

Neutrino interactions



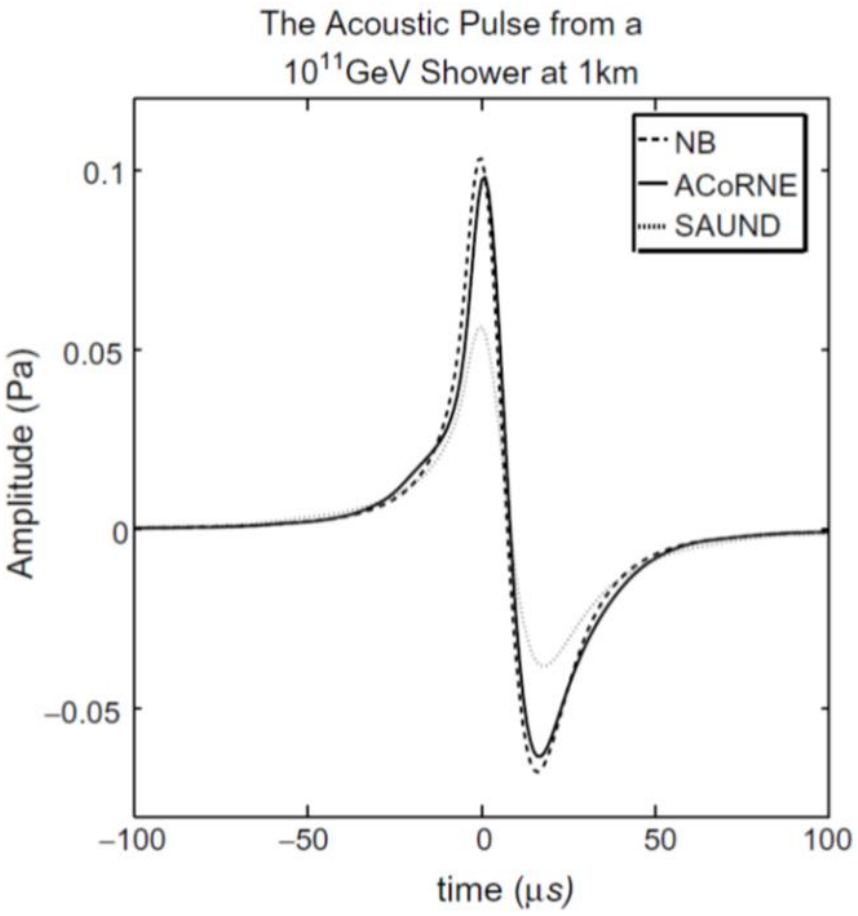


Acoustic signal



Pressure wave detection of neutrino

- Bipolar pulse
- 10 – 50 kHz
- E_ν ~ 10^{14} eV → nPa
- E_ν ~ 10^{21} eV → Pa



Assumptions

- Spectral index
  - $\alpha = 2$
- Bottom up
  - z ~ 2
  - n = 4 $(\mathrm{n} - \alpha = 2)$
- Top down
  - z ~ 20
  - n = 2 $(\mathrm{n} - \alpha = 0)$
- Quasi degenerate neutrino mass
  - $m_\nu = 0.1\mathrm{eV}$
- Flat universe
  Density parameters (Ω) & hubble constant (h) from Planck 2015 data
- $\nu \Leftrightarrow \bar{\nu}$

  $\nu_e \Leftrightarrow \nu_\mu \Leftrightarrow \nu_\tau$