

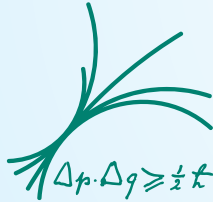
# Neutrino Applications

or

What kind of dreams do physicists have?

July 2019

I.Abt, MPI München



Max-Planck-Institut für Physik  
(Werner-Heisenberg-Institut)



# Neutrino Applications

- **The Usual Misunderstanding**
- **Neutrino Astrophysics**
- **Geoneutrinos**
  - **What Could We Learn About Mother Earth**
- **Neutrino Beams**
  - **Science**
  - **Earth Tomography**
  - **Destroy Nuclear Devices [and what else]**



# The Usual Misunderstanding

**Science fiction uses neutrino beacons to send signals through dense or turbulent matter.**

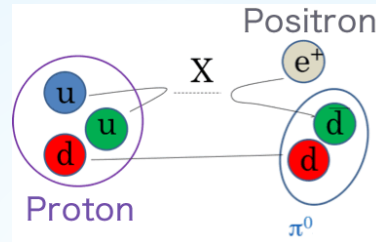


**Well, this could be done, but, neutrinos do not scatter and cannot be detected.**

**The US navy took its time to understand that. Equipping every submarine with a 200 t neutrino receiver was, in the end, not considered reasonable.**

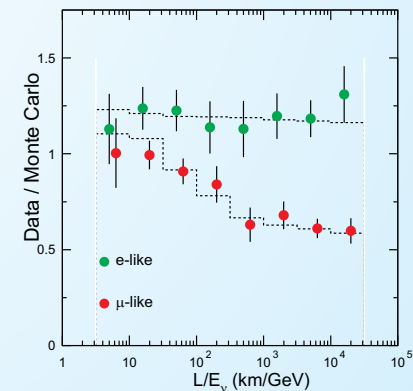
# Neutrino Astrophysics

Neutrino Astrophysics was born by  
Proton Decay



Solar Neutrinos were  
debated a lot.

Atmospheric neutrinos  
established  
neutrino  
oscillations!



Kamiokande  
Phys.Ref.Lett 81, 1998

# Neutrino Astrophysics

Once you know the neutrino parameters, you can look at upwards and downwards going  $e$ ,  $\mu$ ,  $\tau$  from neutrino interactions and , in principle,

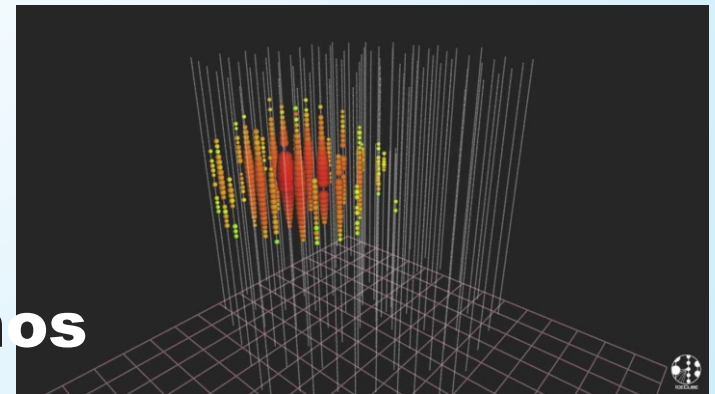
learn about the earth.  $\longrightarrow \longrightarrow$

It does work with muons.  $\longrightarrow$



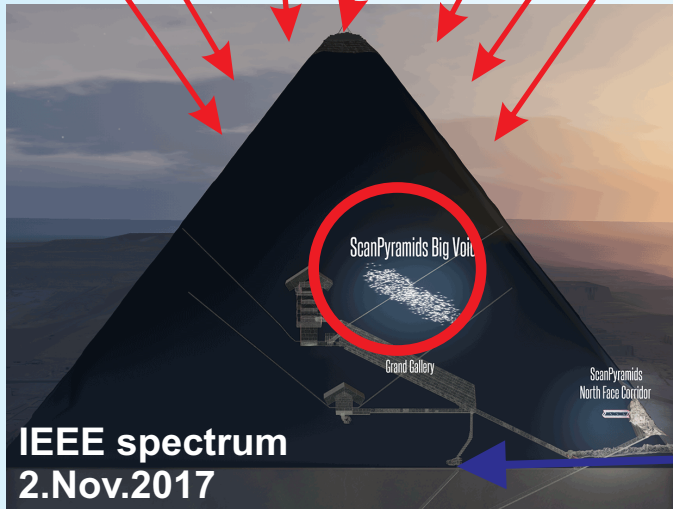
Can also look for extra-galactic high energy neutrinos.

**ICECUBE**  
looks for  
sources of  
PeV neutrinos



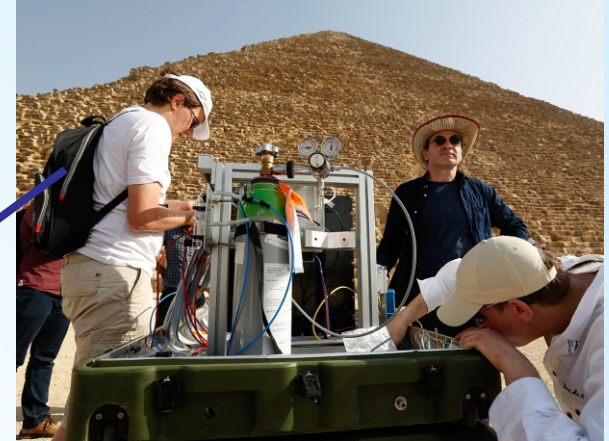


# Muon Scans



**Find  
a new  
voids**

**in the  
Cheops  
pyramid**

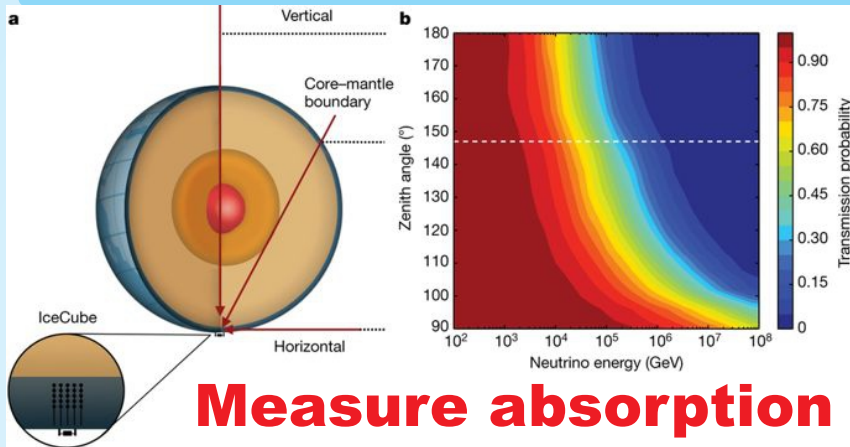


**Overview: NIM A , 878,(2018), 169**

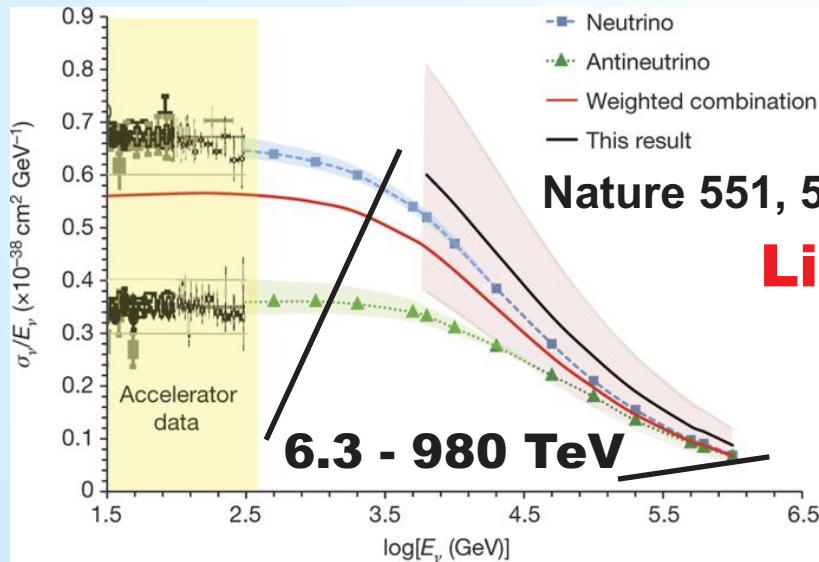
**Security: containers, trains**

**Archeological sites, Volcanoes  
could mean a lot**

# Cosmic Neutrinos and New Physics



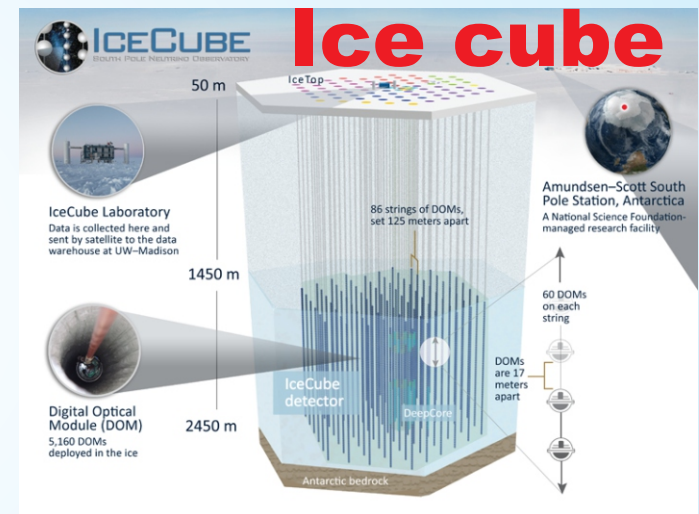
**Measure absorption  
of high energy neutrinos**  
► **measure cross sections**



**High neutrino energy**

► **Large cross section**

► **Large absorption**



**Limit new physics like  
leptoquarks or compact spatial  
dimensions which would in-  
crease cross sections.**



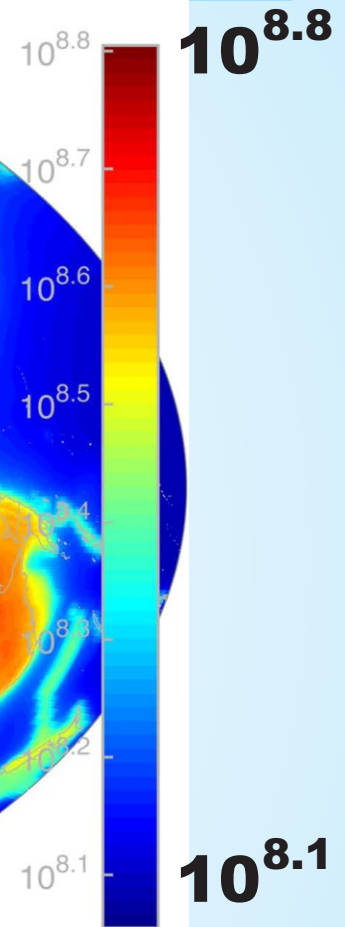
# Geoneutrinos

Earth crust +  
mantle

MC  
+  
Observations

$^{238}\text{U} + ^{232}\text{Th}$

Reactors



$3.4^{+2.3}_{-2.2} 10^{25}$  /s anti electron-neutrinos

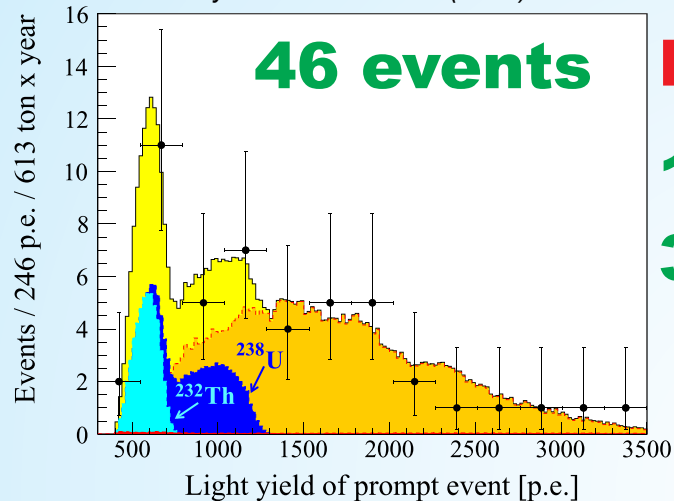
modeling the earth

Scientific Reports 5-13945



# Geoneutrinos

Physics Letters B 722 (2013) 295–300

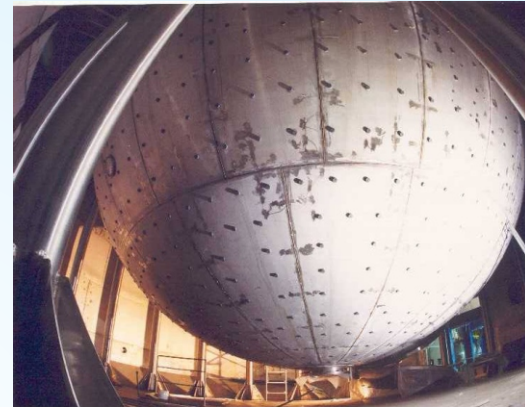


**Borexino**

**1353 days**

**300 t**

**Liquid Scintillator**



**steel,  
water**

**U and Th teach about  
earth's heat balance**

**KAMLAND**

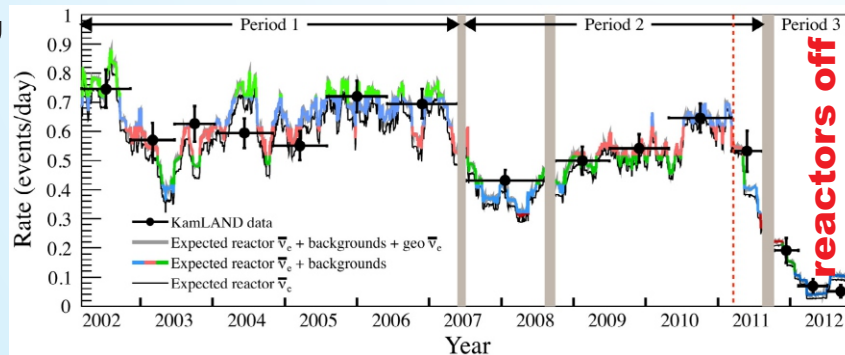
**nylon,**

**oil**

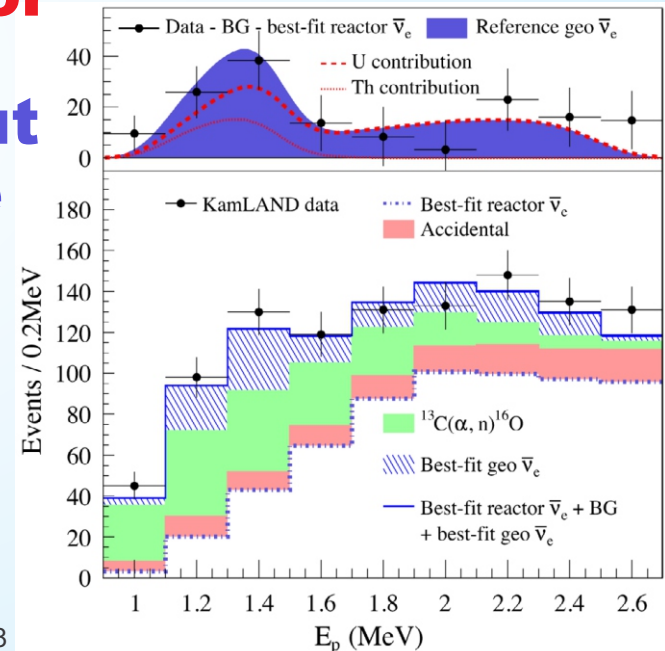
**8.19**

**years**

**1000t**

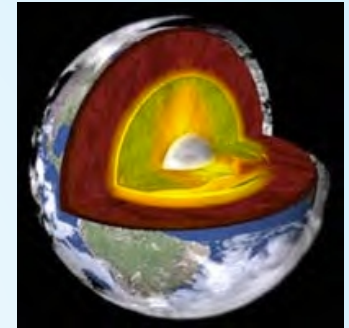


ANNALS OF GEOPHYSICS, 60, 1, 2017, S0113; doi:10.4401/ag-7388



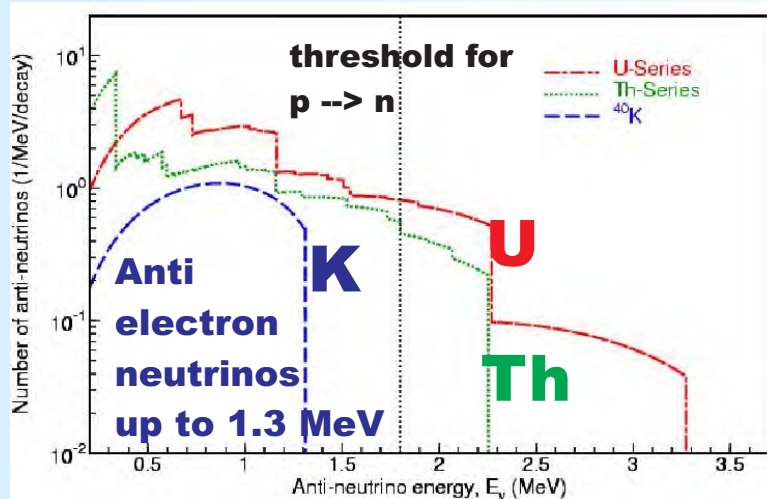
# Geoneutrinos

**How about  $^{40}\text{K}$ ? Makes you radioactive !**  
**Produces 10~20% of radiogenic heat.**



**But how to detect the [anti] neutrinos.** And the Core?

**1.5 MeV Neutrinos are hidden by 10 000 times solar pep neutrinos.**

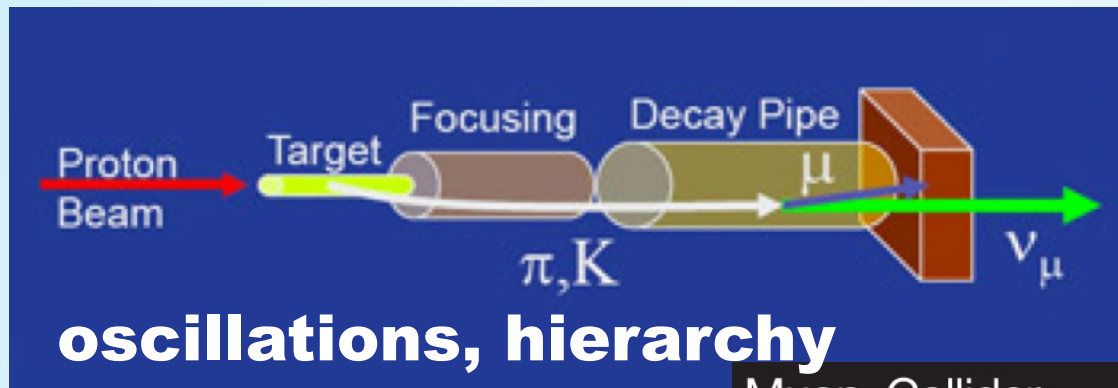


**Antineutrinos are hidden U/Th**

**$(5-15) \times 10^5 \text{ cm}^{-2} \text{ s}^{-1}$  44 keV Neutrinos**

**Need a (mobile) low threshold directional recoil detector or giant tanks of  $^{14}\text{N}$  /  $^{35}\text{Cl}$  .** ► **Your chance to fame**

# Neutrino Beams



**This is today.**

- **some TeV**
- **till the target melts**

**This is tomorrow.**

- **some TeV**
- **more intensity**

**Penetrate the earth**

**Need to steer the beam**

► **float in the ocean.**

## Muon Collider Conceptual Layout

### Project X

Accelerate hydrogen ions to 8 GeV using SRF technology.

### Compressor Ring

Reduce size of beam.

### Target

Collisions lead to muons with energy of about 200 MeV.

### Muon Capture and Cooling

Capture, bunch and cool muons to create a tight beam.

### Initial Acceleration

In a dozen turns, accelerate muons to 20 GeV.

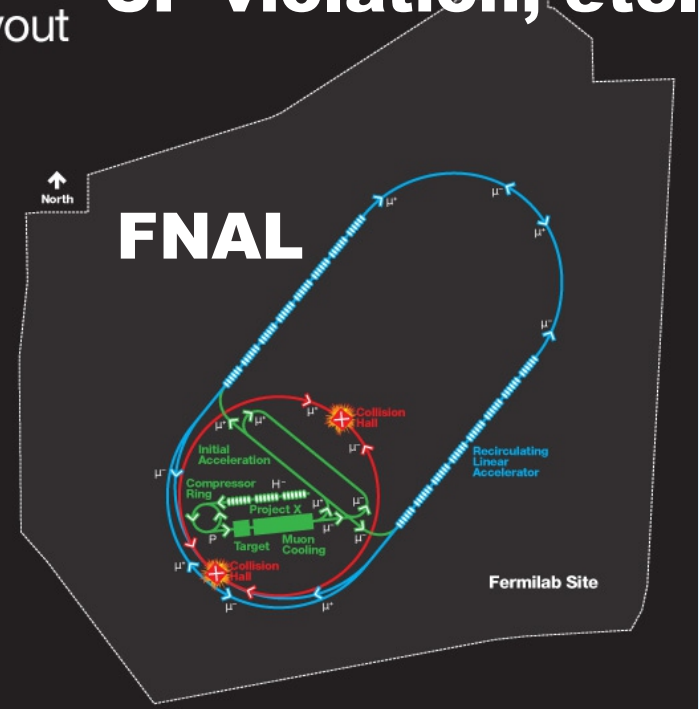
### Recirculating Linear Accelerator

In a number of turns, accelerate muons up to 2 TeV using SRF technology.

### Collider Ring

Bring positive and negative muons into collision at two locations 100 meters underground.

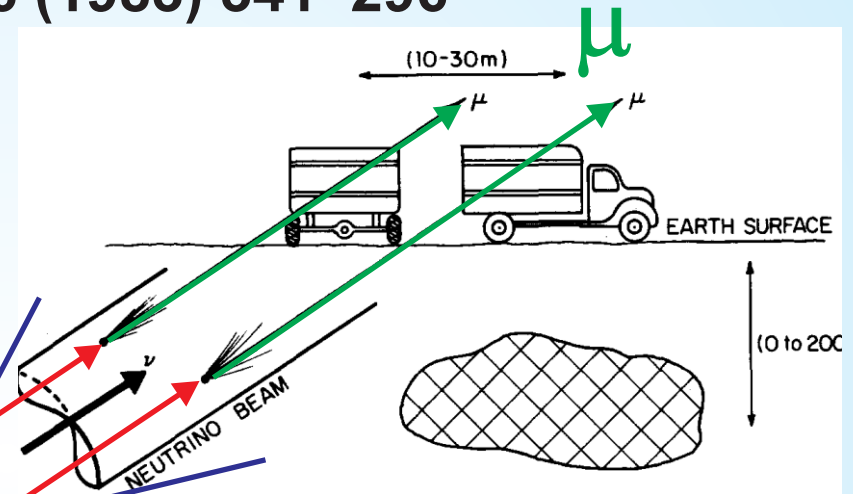
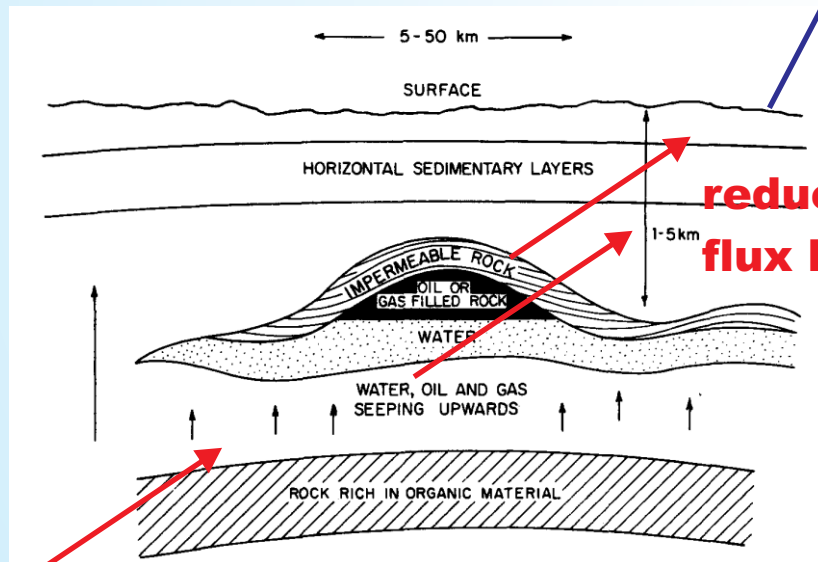
**CP violation, etc.**



# Laboratories

PHYSICS REPORTS 99, No.6 (1983) 341–296

**Search for oil  
or other deposits  
close to the surface.**



**Measure muon flux**

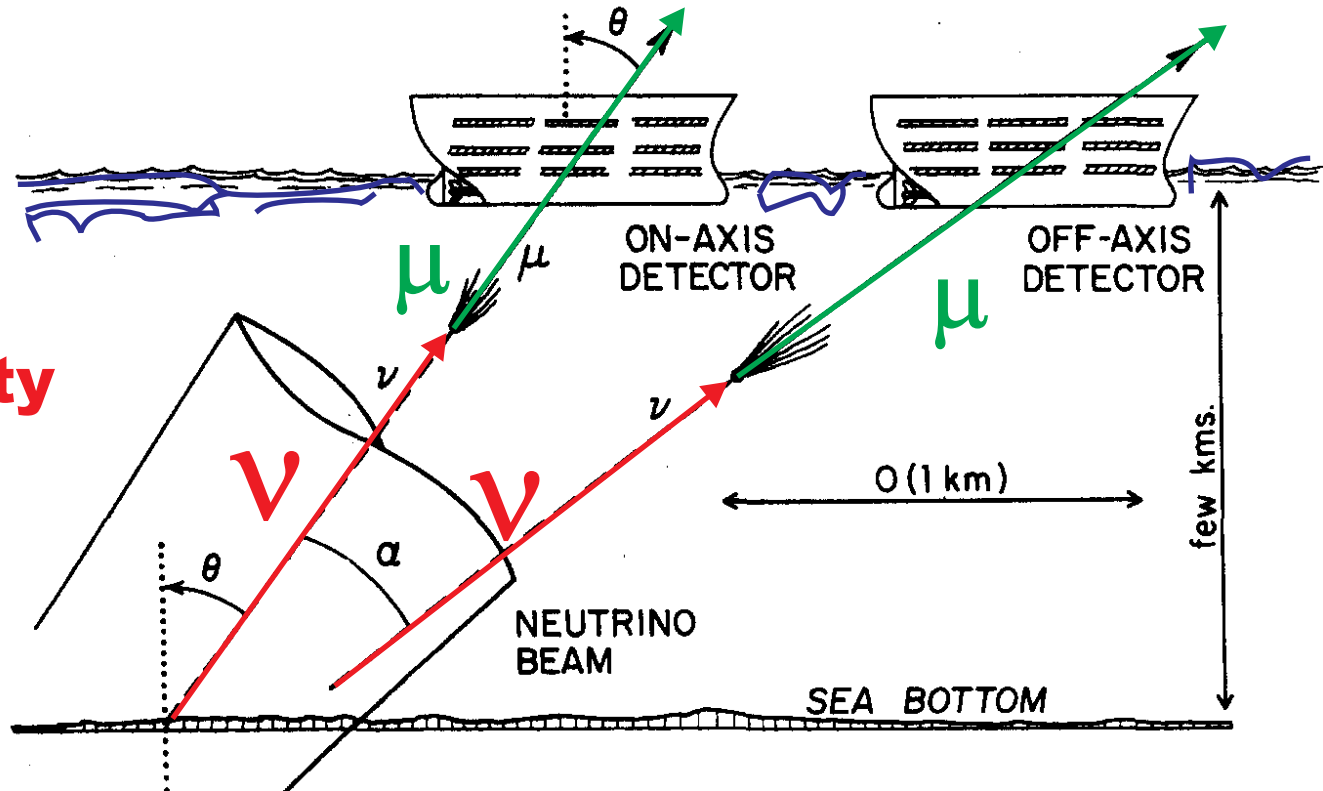
**Your accelerator  
is best if it can move  
around.**



# Earth Tomography

**Need  
energy  
and  
intensity**

►  
**Super-  
beams**



**Use on-axis and off-axis neutrinos and scan  
earth density with different energies.**

**This assumes SM cross sections.**

# And Finally

**Build a 1000 TeV high intensity neutrino beam :**



**Neutrino cross-section grows with  $A$**

- ▶ **neutrinos interact with plutonium**
- ▶ **energy gets deposited and**
- ▶ **nuclei evaporate neutrons**

**destroy nukes  
remotely**

**▶ chain reaction or meltdown**

arXiv:0306062(2003)

**Build two beams and cross them somewhere  
at the Z resonance: Zs decay ▶ see above**

**destroy anything  
remotely**



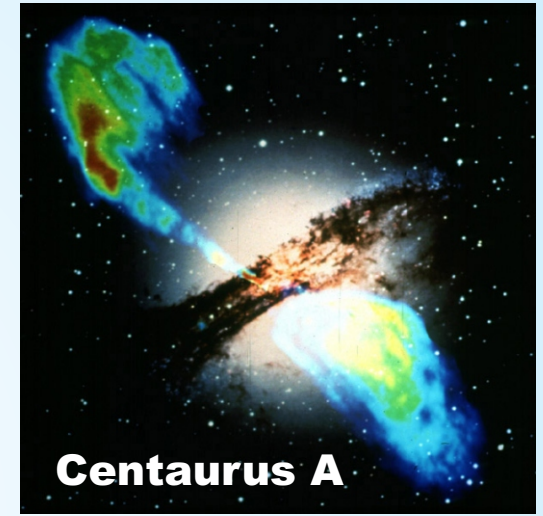
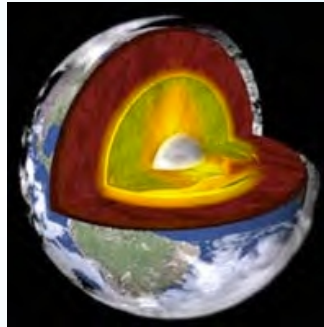
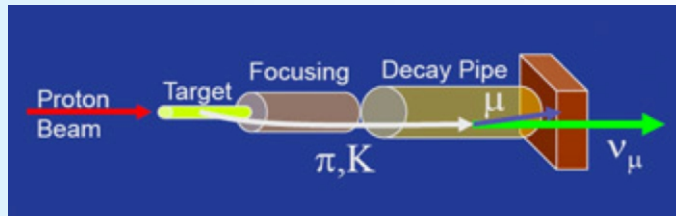
arXiv:0805.3991(2008)

**Do not worry!**



# Neutrinos are Great

- to learn about the universe
- to learn about the nature of matter
- to learn about earth



**Centaurus A**

**MPI Radioastronomie**

- to appear in science fiction movies
- to give people strange ideas

