Muon and neutrinos for Earth studies

Paolo Strolin (Univ. Federico II and INFN, Napoli)

MNR 2013 @ Tokyo, July 25-26, 2013

NIHONBASHI BRIDGE AT EDO TOWARD TOKKAIDO ROAD AND MT. FUJI (1863)

Utagawa Sadahide - Near end of Tokugawa period (1603-1868)

[http://www.myjapanesehanga.com/home/artists/utagawa-sadahide-1807-1873/view-of-a-daimyo-procession-at-nihonbashi]

The World is always changing

In an extension of the talk
I will come to this point regarding
Science and Science Education in present times

THE NEWLY BUILT NIHONBASHI BRIDGE (1911)
An impressive change of townscape at the end of the Meji period (1868-1912)

[http://commons.wikimedia.org/wiki/File:NewlyBuilt_Nihonbashi_1911_Tokyo.jpg]

THE NIHONBASHI HISTORIC BRIDGE

A new change of townscape in recent years

[http://en.wikipedia.org/wiki/Nihonbashi]

Here in 2008 following pioneering volcano muographies in Japan

As today, thanks to Tokyo University:
excellence in basic Science and foresight for applications

A growing community

First Workshop — *Tokyo 2008*

Other Workshops — *Napoli 2008 - Bern 2009 - Tokyo 2010*
Napoli 2010 - Tokyo 2011

MNR 2012
Clermont Ferrand

MNR 2013
Tokyo

Who will host MNR 2014 ?

J.-M. Folon (1934-2005)

A growing tree:
muons and neutrinos for Earth studies

Dreams

Season of results

Breakthroughs

Deep roots in basic Science

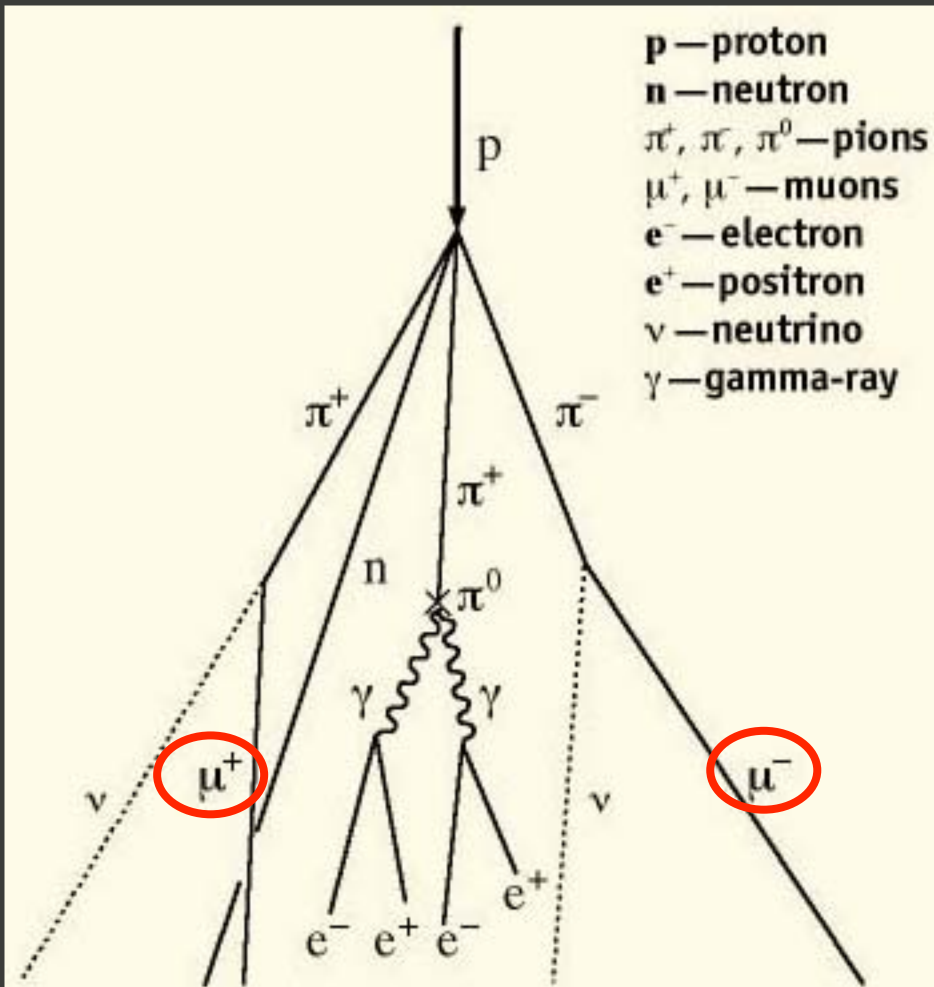
Muons

The incredible discovery of cosmic rays (1911-12)

Viktor F. Hess (centre)

with ionization measuring equipment on a hydrogen balloon at altitudes up to 5.3 km, at serious personal risk

From cosmic rays to Muography




G.B. Lusieri (1755-1821)

1935

Yukawa: “π meson” hypothesis

1937

Anderson-Neddermayer

“.. particles less massive than protons but more penetrating than electrons”

produced by cosmic rays

Thought to be π

1947

Conversi-Pancini-Piccioni

No strong interactions: not π

“Muons” are born!

↓

“Muography”

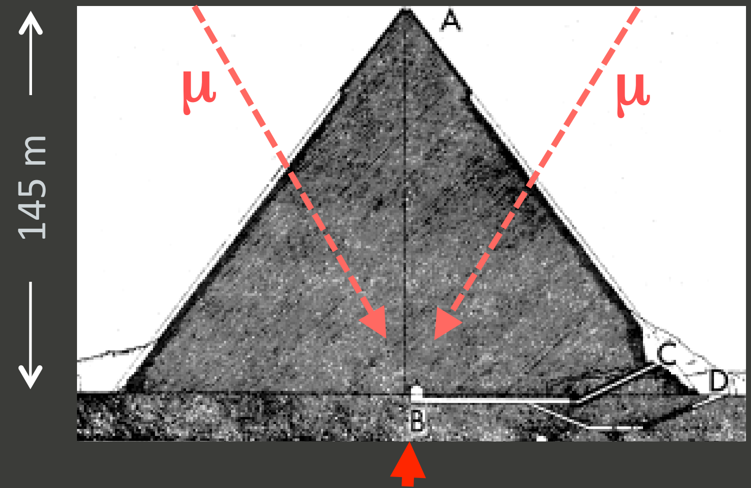
The flavour of early times of muography

Cosmic Rays Measure Overburden of Tunnel

Fig. 1—Geiger counter "telescope" in operation in the Guthega-Munyang tunnel. From left are Dr. George and his assistants, Mr. Lehane and Mr. O'Neill.

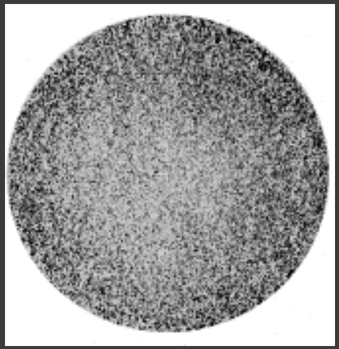
Rock thickness by muon absorption

E. P. George, Commonwealth Eng. (1955) 455

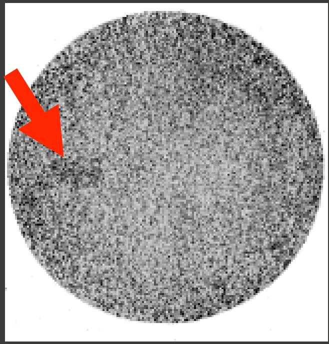


Spark Chamber muon telescope

Data: no chamber



Simulation: hidden chamber



Search for hidden chambers in the Chephren's Pyramid

L.W. Alvarez et al. Science 167 (1970) 832

The seminal work on volcano muography

Kanetada Nagamine

Geo-tomographic observation of inner structure of volcano with cosmic ray muons (in Japanese)

Journal of Geography 104 (1995) 998

Kanetada Nagamine, M. Iwasaki, K. Shimomura and K. Ishida

Methods of probing inner structure of geophysical substance with the horizontal cosmic-ray muons and possible application to volcanic eruption prediction

Nucl. Instr. and Meth. A356 (1995) 585

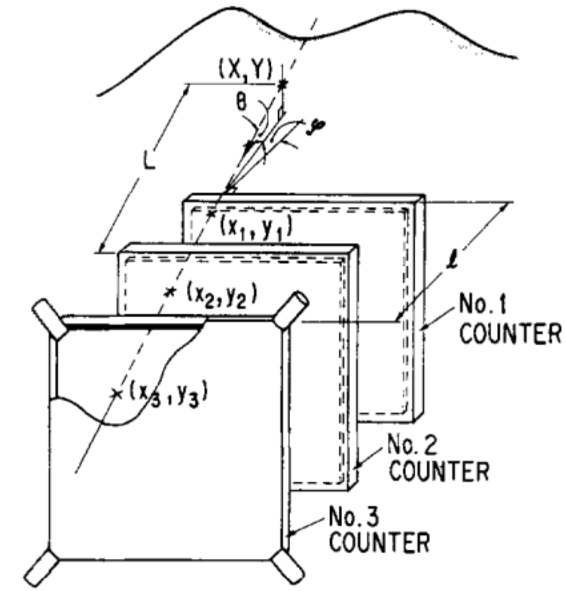
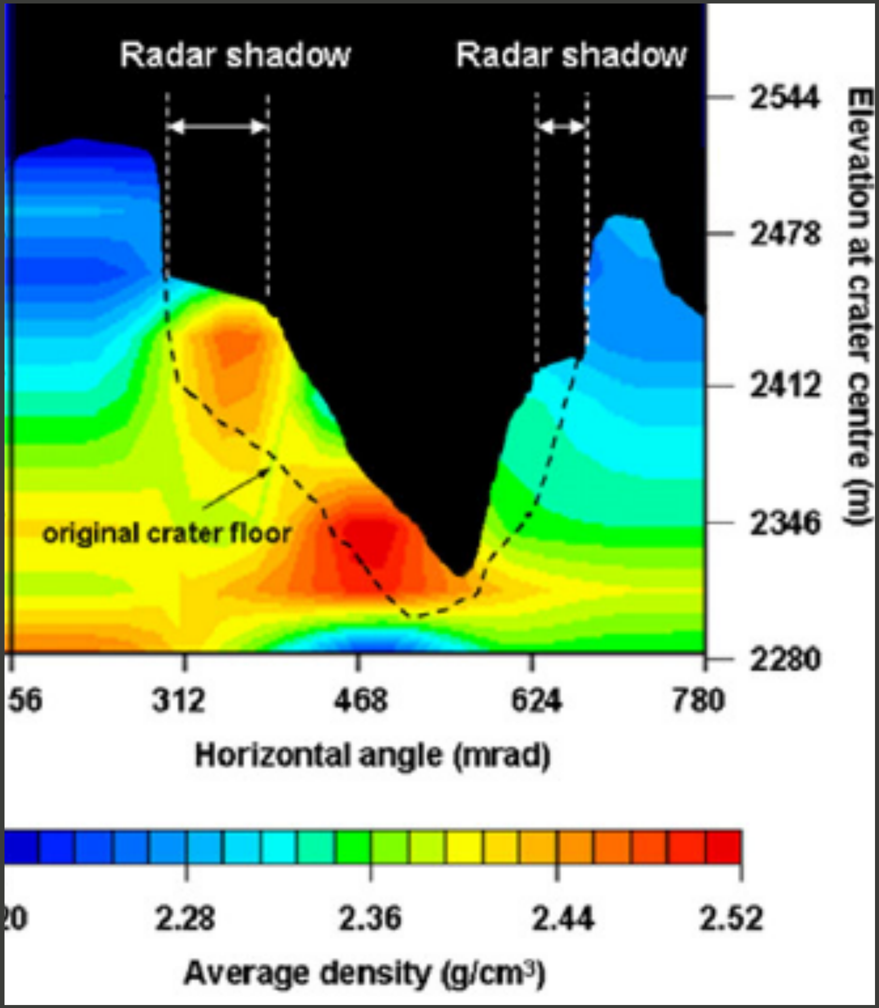


Fig. 3. Counter telescope comprising three plastic scintillators used for the Mt. Tsukuba measurement.

Test measurement

"it was made clear that nearly horizontal cosmic-ray muons can be used to explore the inner-structure of a gigantic geophysical substance, such as the top region of a volcano"

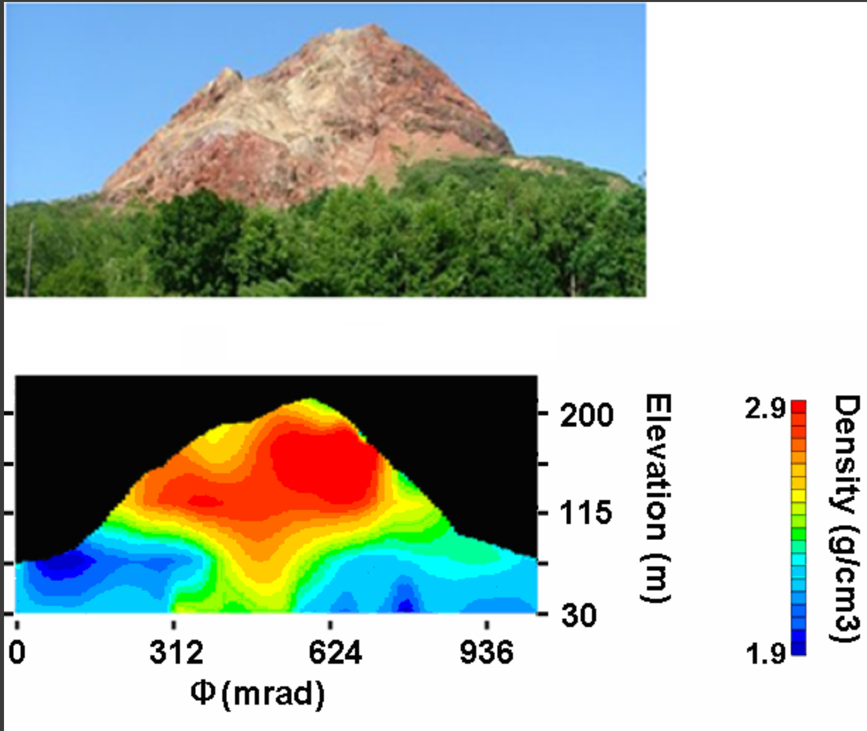
Breakthrough with volcanoes in Japan



Mt. Asama

H.K.M. Tanaka et al. (2007)

EPS Lett. 263 (2007)104

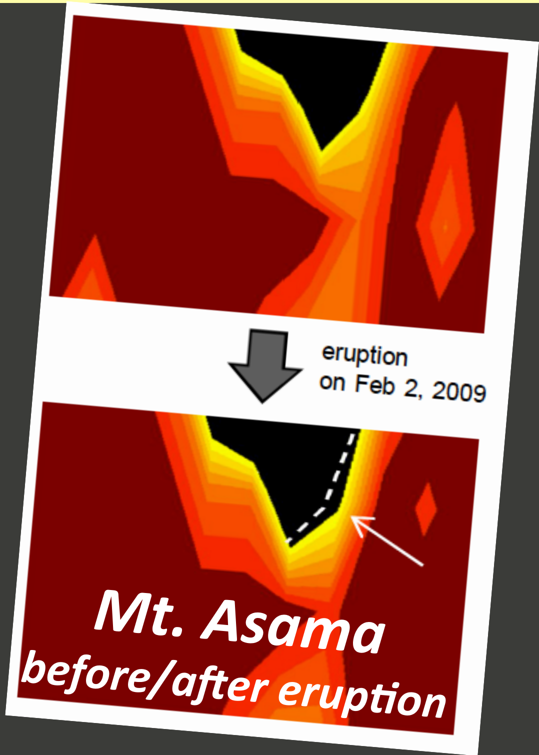


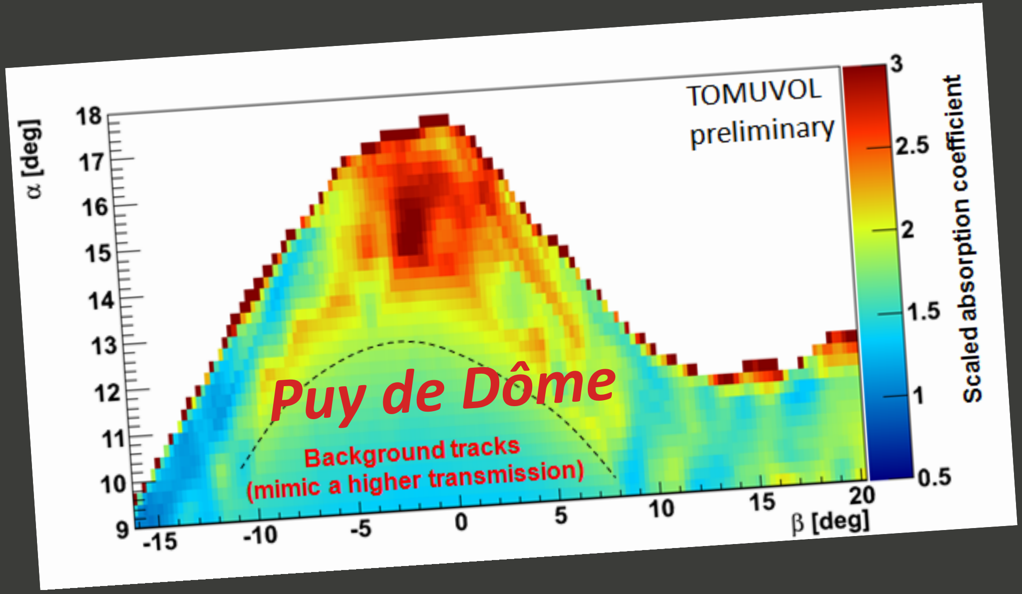
Showa-Shinzan lava dome at Usu volcano

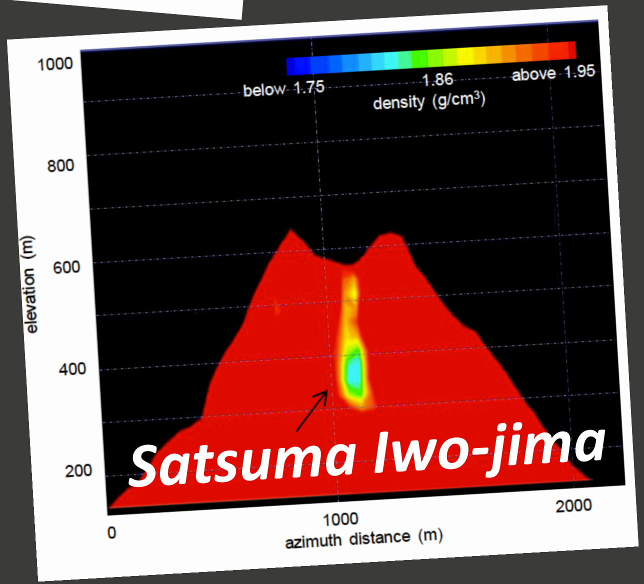
H.K.M. Tanaka and I. Yokoyama

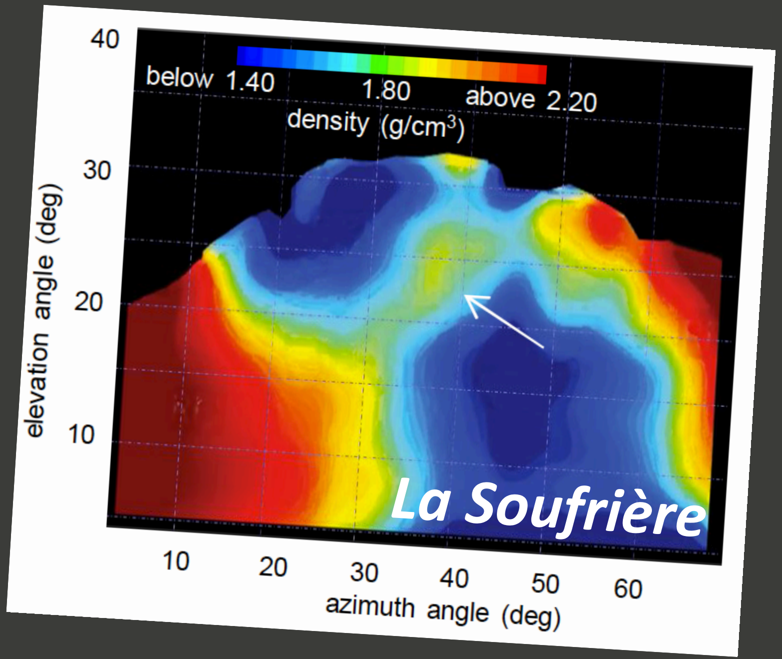
Proc. Jpn. Acad. B84 (2008) 107

Further results: more at the Workshop









Controlled Test of Geophysical Tomography

Douglas Bryman*
University of British Columbia

Collaboration
AAPS, Bern, Geological Survey of Canada, Nyrstar, UBC

- **A successful field trial has been performed with muon geotomography imaging a known massive sulfide deposit in a complex geological environment**

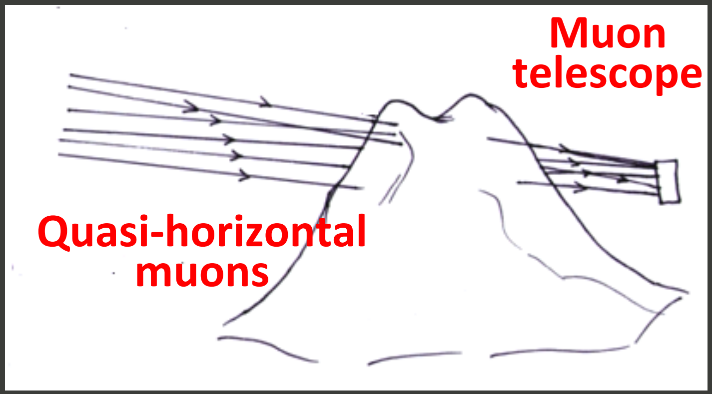
- **<u>Inverted 3D density contrast images of the deposit are similar to a model derived from drill data</u>**
(total mass, mass distribution, and host rock densities were reproduced

- **Several exploration surveys are underway**

*doug@triumf.ca

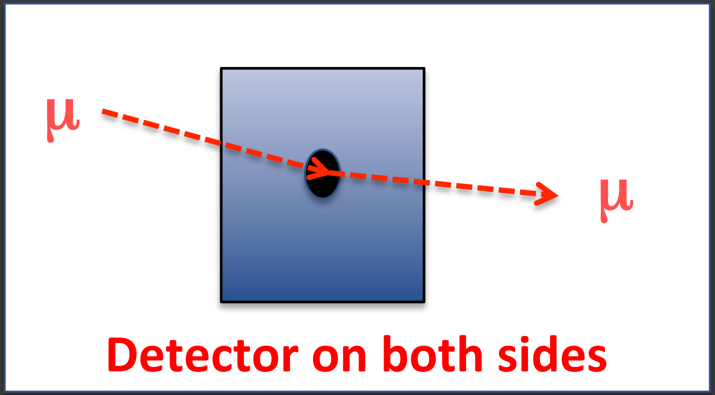
Methods and applications

Absorption (density)



Multi-parameter combined analysis with resistivity and gravity data

Scattering (Z^2)



Suitable for high Z materials

Archaeology
Civil Engineering
Security
Uranium in radioactive waste
Geological structures and mining
Volcanoes ......

Detection techniques

Initially

Electronic techniques

Breakthrough

Nuclear Emulsion

High space resolution, transportability, no electric supply

Future: choose detector according to application

Nuclear Emulsion

Electronic detectors with high space resolution

Large area, long exposures → high sensitivity

- ***Plastic scintillators** with Si Photo-Multipliers (MU-RAY)*

  Low power consumption, background rejection by time of flight

- ***Resistive Plate Chambers** (TOMUVOL)*

  Ease of large area, need HV and gas supply

- *…….*

More at this Workshop!

Dreams

Results

Activities

Neutrinos

Roots in basic physics

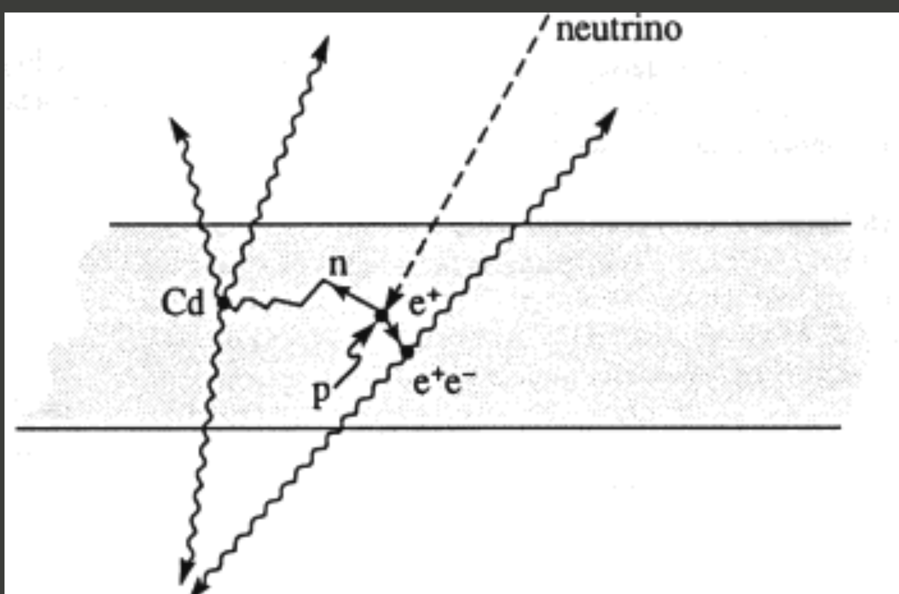
1930 **Pauli: neutrino hypothesis as "desperate remedy" to save energy conservation in β-decay**

1933 **Fermi: phenomenological theory of β-decay**

1956 **Reines and Cowan observe reactor anti-neutrinos**

Detection of inverse β-decay

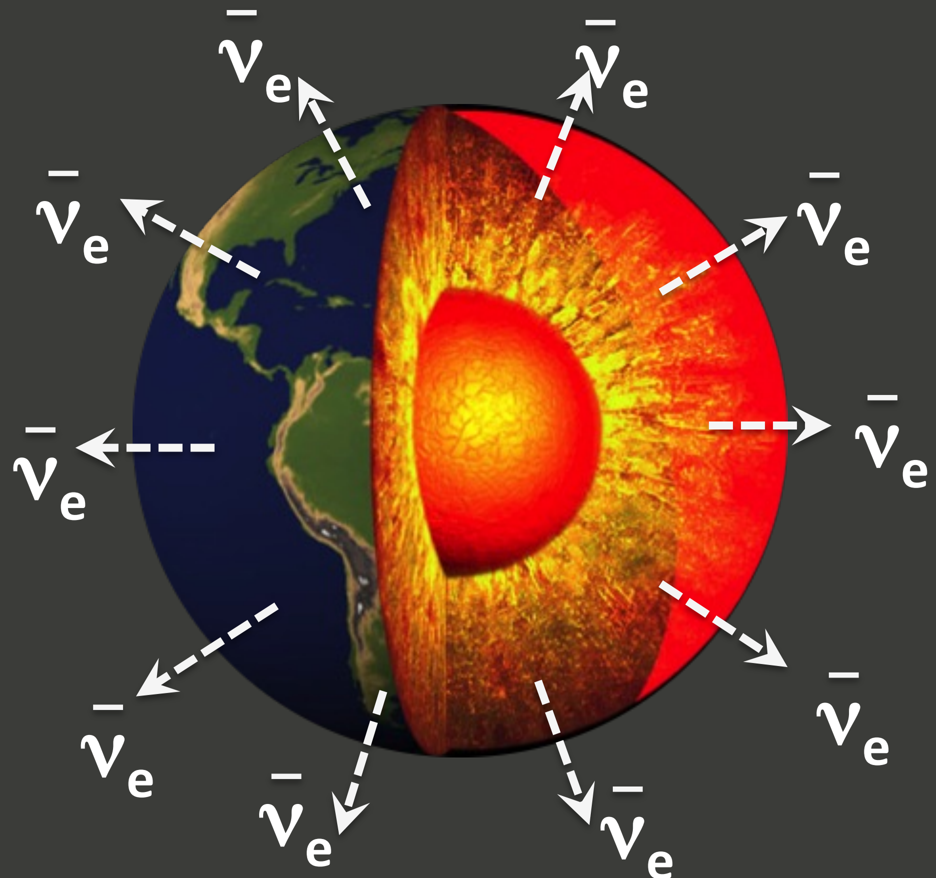
Water + liquid scintillator (0.2 ton)



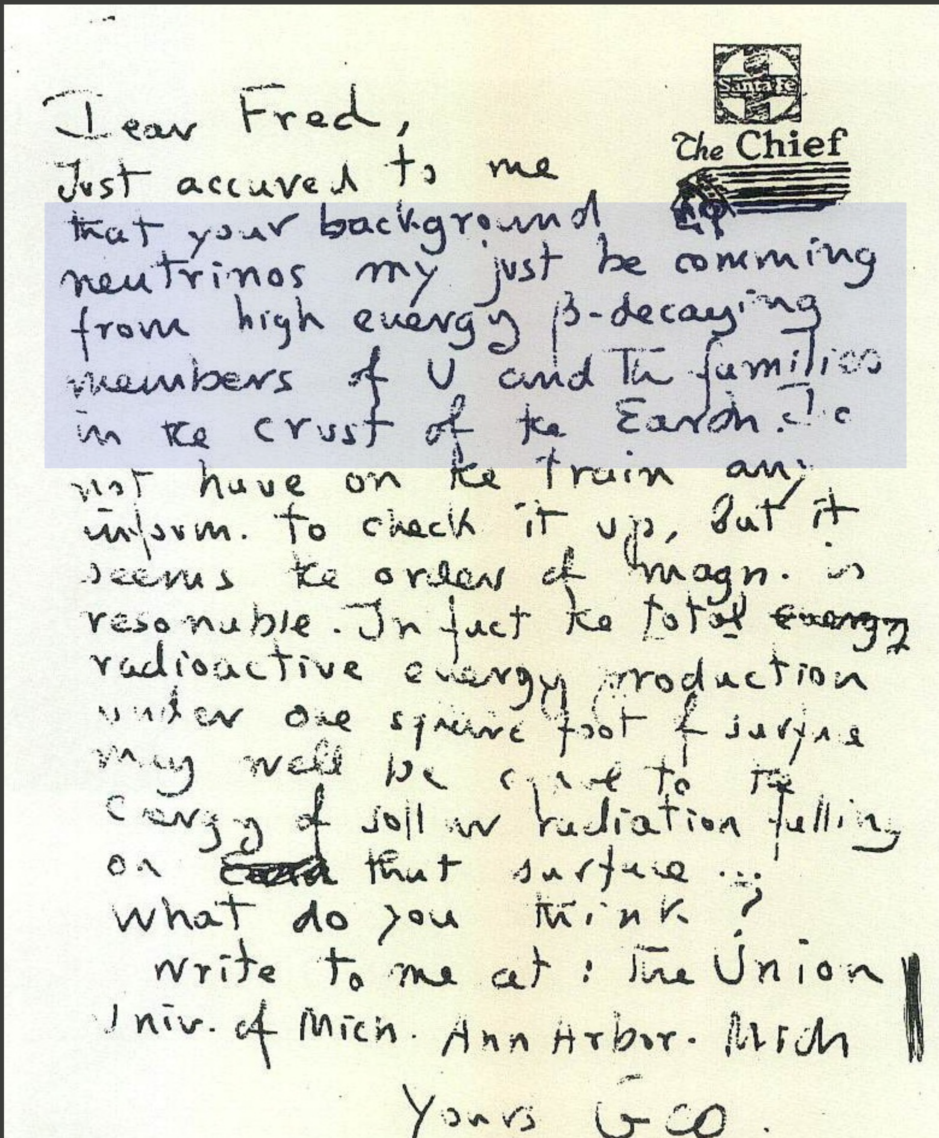
Prompt γs from e+ annihilation

Delayed coincidence with γs from n-capture in ^{108}Cd doping

Geo-neutrinos



The first suggestion of geo-neutrinos: a potential “background” in the discovery of neutrinos



Santa Fe
The Chief

Dear Fred,
Just accured to me
that your background
neutrinos my just be comming
from high energy β-decaying
members of U and Th families
in the crust of the Earth. I do
not have on the train any
inform. to check it up, but it
seems the order of magn. is
resonable. In fact the total
radioactive energy production
under one square foot of surface
may well be equal to the
energy of soil radiation falling
on that surface...
What do you think?
Write to me at: The Union
Univ. of Mich. Ann Arbor. Mich
Yours Geo.

G. Gamow (1904-1968)

George Gamow (Georgiy Gamov)
Letter to F. Reines (1953)

Dear Fred,
… your background neutrinos may just be coming from high energy β-decaying members of U and Th families in the crust of the Earth ...

Ideas

G. Marx (1927-2002)

G. Eder (1929-2000)

G. Marx and **N. Menyhard**
Über die Perspektiven der Neutrino-Astronomie
Mitteilungen der Sternwarte Budapest 48 (1960)

G. Eder: *Terrestrial neutrinos*, Nucl. Phys. 78 (1966)

Arguments are given for a remarkable abundance of radioactive elements within the Earth. Methods are discussed in order to measure this abundance by neutrino experiments.

G. Marx: *Geophysics by neutrinos*
Czechoslovak Journal of Physics B 19 (1969)

… Searching the Sun with a neutrino telescope is well under way [Davies et al. 1968].

The present paper is concentrated on the second important task of neutrino physics: the Earth ….

…………………
…………………

Practical proposal

R. Raghavan(1937-2011)

R. Raghavan et al.
Measuring the global radioactivity in the earth by multi-detector antineutrino spectroscopy
Phys. Rev. Lett. 80 (1998)

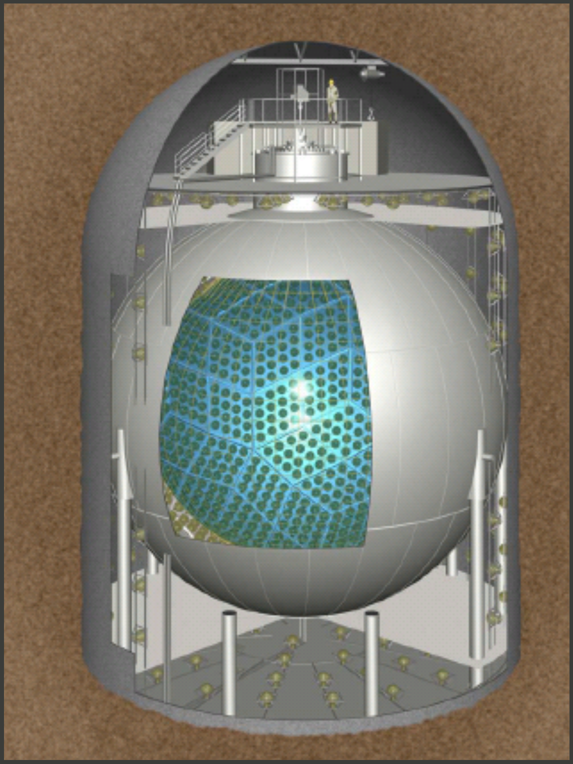
We show that electron antineutrino spectroscopy in <u>upcoming detectors in Italy and Japan</u> can be used to measure the separate global abundances of ^{238}U and ^{232}Th, thus ~ 90% of the radiogenic heat in the Earth.

Exploiting the unique advantage of their contrasting geological locations, they may also probe differences in U,Th areal densities in the continental and oceanic crusts and the mantle. ….

From Reines-Cowan's detector to present

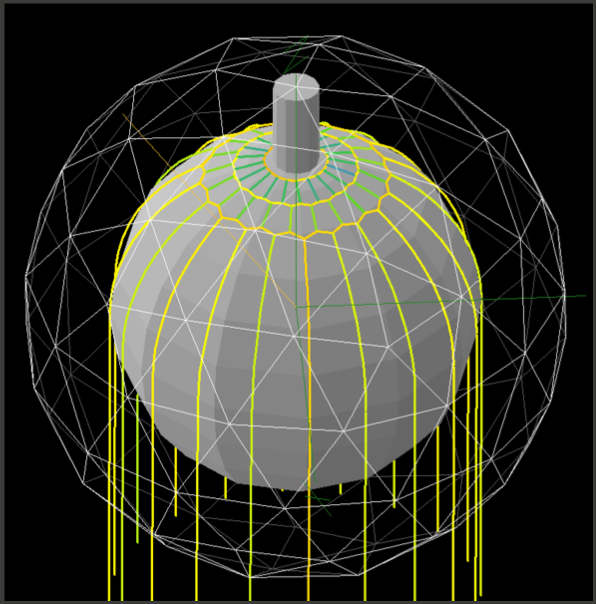
low threshold - low noise (radiopurity, underground) - high space resolution Liquid Scintillator neutrino detectors

KamLAND
1900 PMTs, 1 kt
> 2002

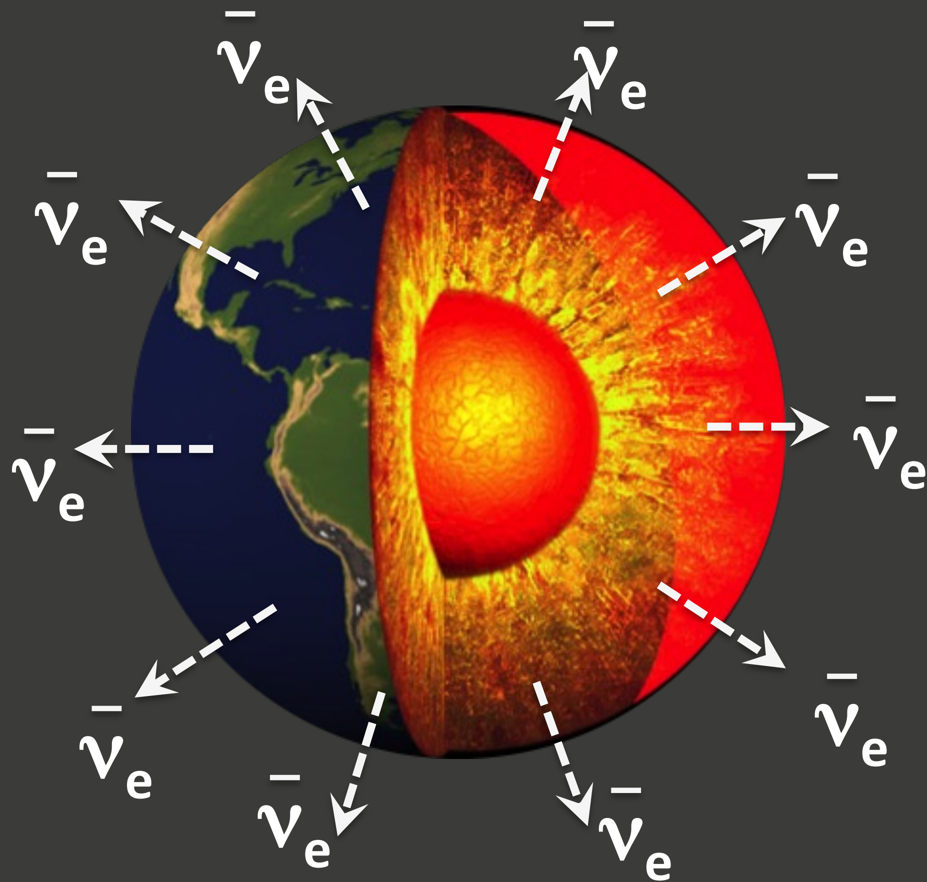


Borexino
2200 PMTs, 0.3 kt
> 2007

SNO+
10000 PMTs, 0.6 kt
> 2014



Geo-neutrinos detected!



2005 KamLAND: first geo-neutrinos

2010 Borexino: signal with low background from nuclear reactors

2011 Signal leaves room for primordial heat

2013 Combined analysis: Mantle signal

THE BACKGROUND

feared by Gamow for neutrino detection in Reines-Cowan experiment

↓

THE SIGNAL

for Earth studies!

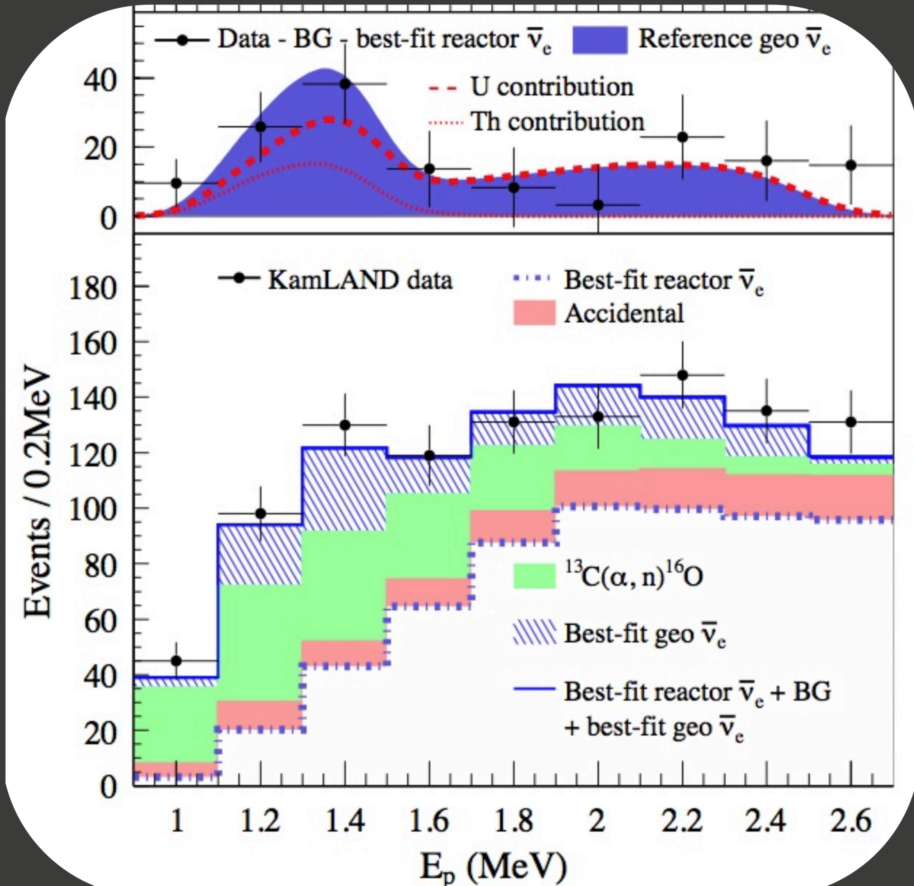
With view confined to basic physics the usual saying is

“The discovery of today is the background of tomorrow”

Geo-neutrinos 2013

KamLAND

Gando et al 2013

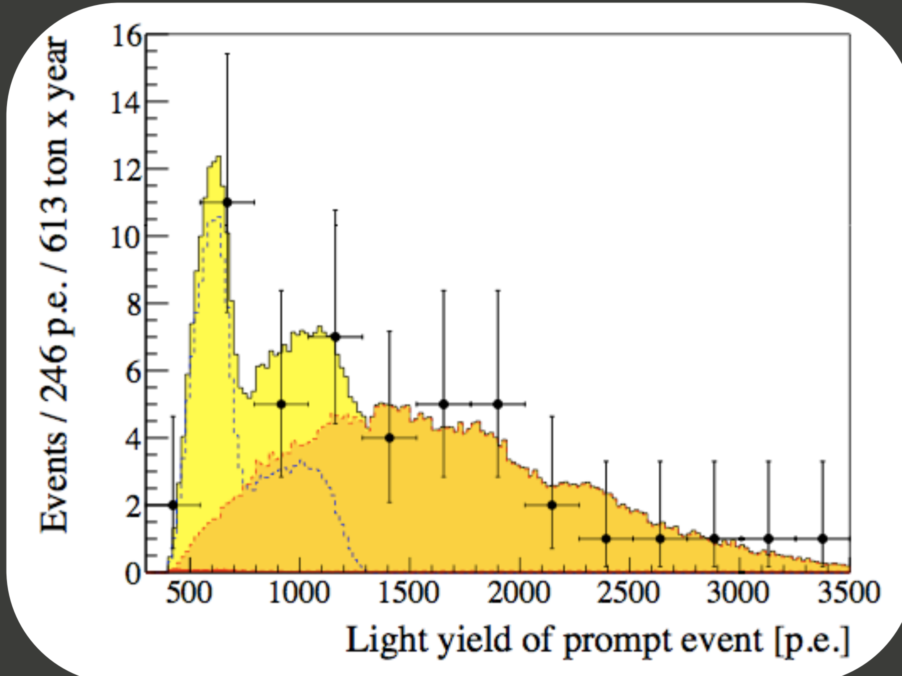


$N_{geo} = (116^{+28}_{-27})$

(large b.g. from reactors)

Borexino

Bellini et al 2013



$N_{geo} = (14.3 \pm 4.4)$

$N_{rea} = (31.2^{+7.0}_{-6.1})$

Geo-neutrinos from Mantle
(combined analysis Borexino – KamLand)

$$\text{Signal}_{geo} = S(\text{Crust}) + S(\text{Mantle}) = 38.3\ ^{+10.3}_{-9.9}\ \text{TNU}$$

By subtracting estimated signal from Crust

S(Mantle) = (14.1 $\pm$ 8.1) TNU

1 Terrestrial Neutrino Unit (TNU) = number of events detected during one year with a target of 10^{32} protons (~ 1 kton of liquid scintillator)

Where the Earth's heat come from?

(even children can ask such a question)

"Radiogenic" heat comes from the energy delivered in radioactive nuclear decays (mainly U and Th)

Radiogenic heat estimated from geo-neutrino flux is insufficient to explain the total heat

↓

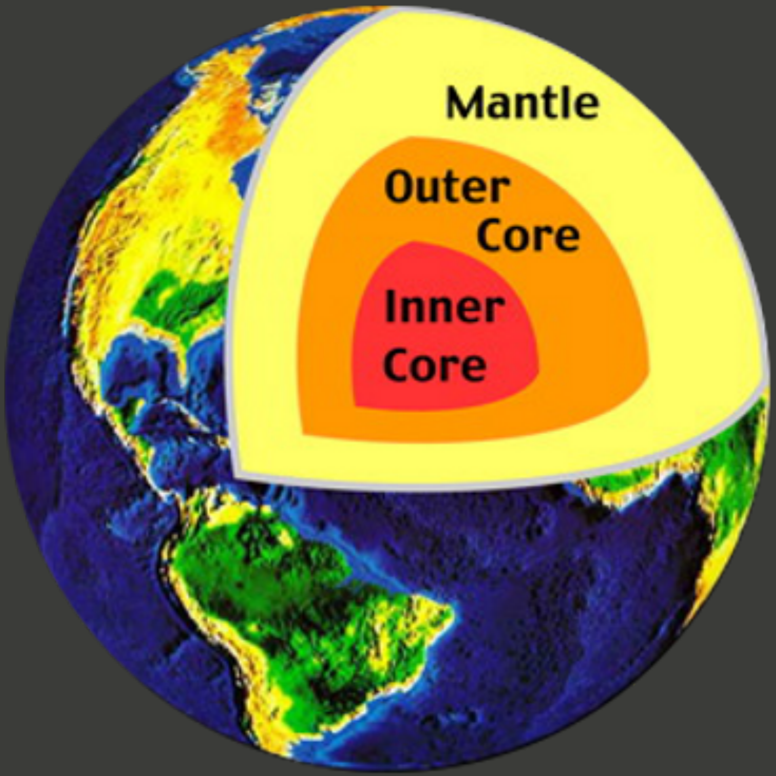
Need of substantial but not dominant contribution from Earth's primordial heat supply

More at this Workshop!

Dreams

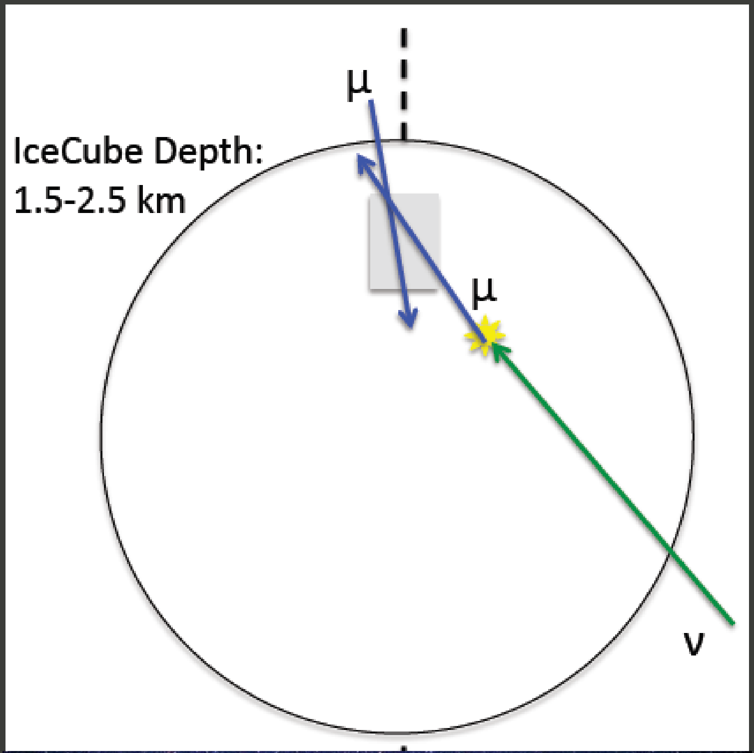
Detailed results

High energy neutrinos to explore the Earth's core



Basic Science: "Neutrino astronomy"

Other messengers (light, …) suffer absorption or deviation



"Neutrino telescope" sees Čerenkov light produced by muons in water or ice

↑

Neutrinos interacting close to surface generate muons reaching detector:
Earth as converter

↑

Neutrinos from far Cosmos at Antipodes go through Earth

“Neutrino Telescope” in deep Anctartic ice

ICECUBE
SOUTH POLE NEUTRINO OBSERVATORY

Photo-Multiplier tubes see the Čerenkov light

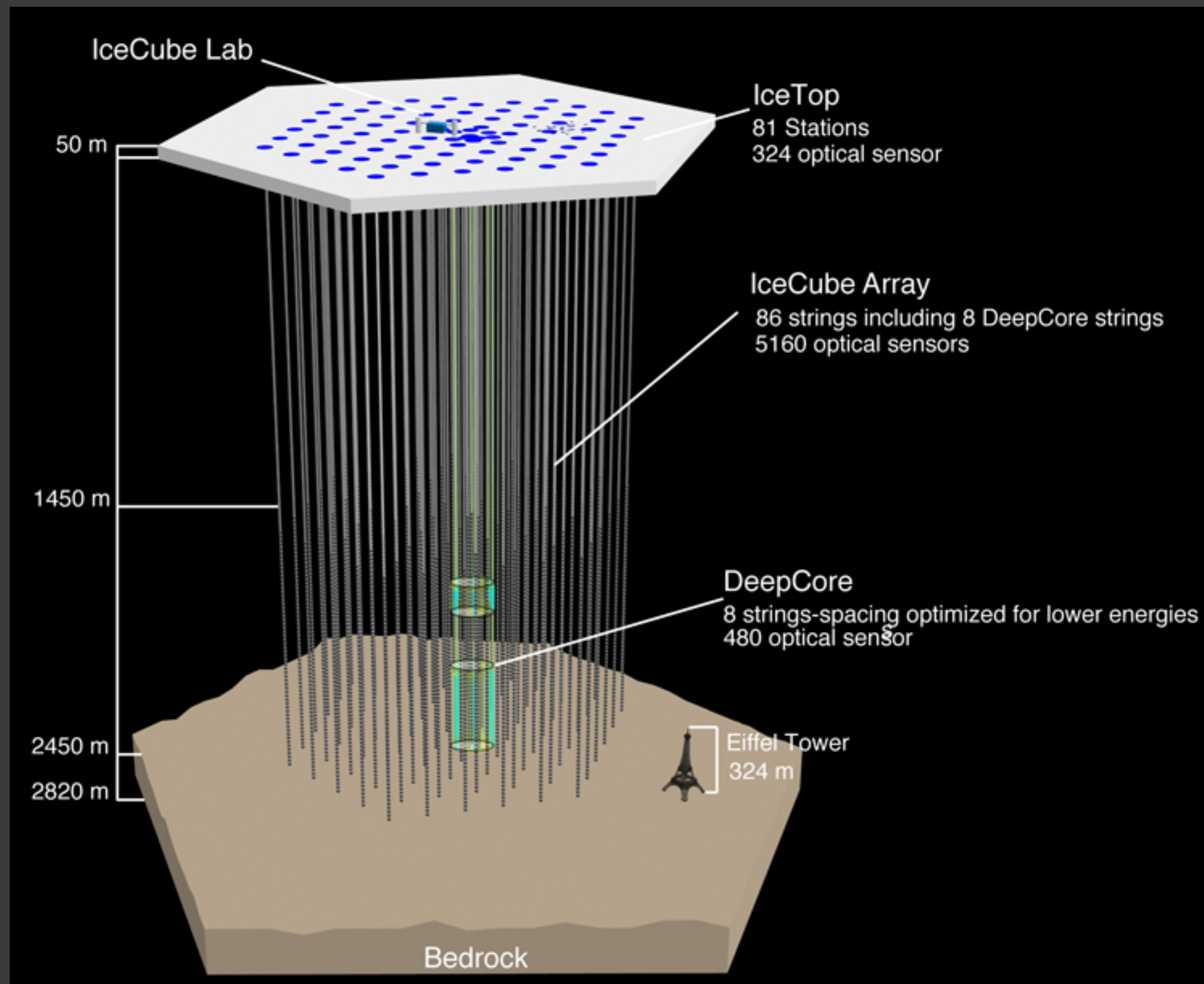
Strings of PM tubes

Array of PM Strings

5160 PM tubes

1450-2450 m depth

! Km2 area

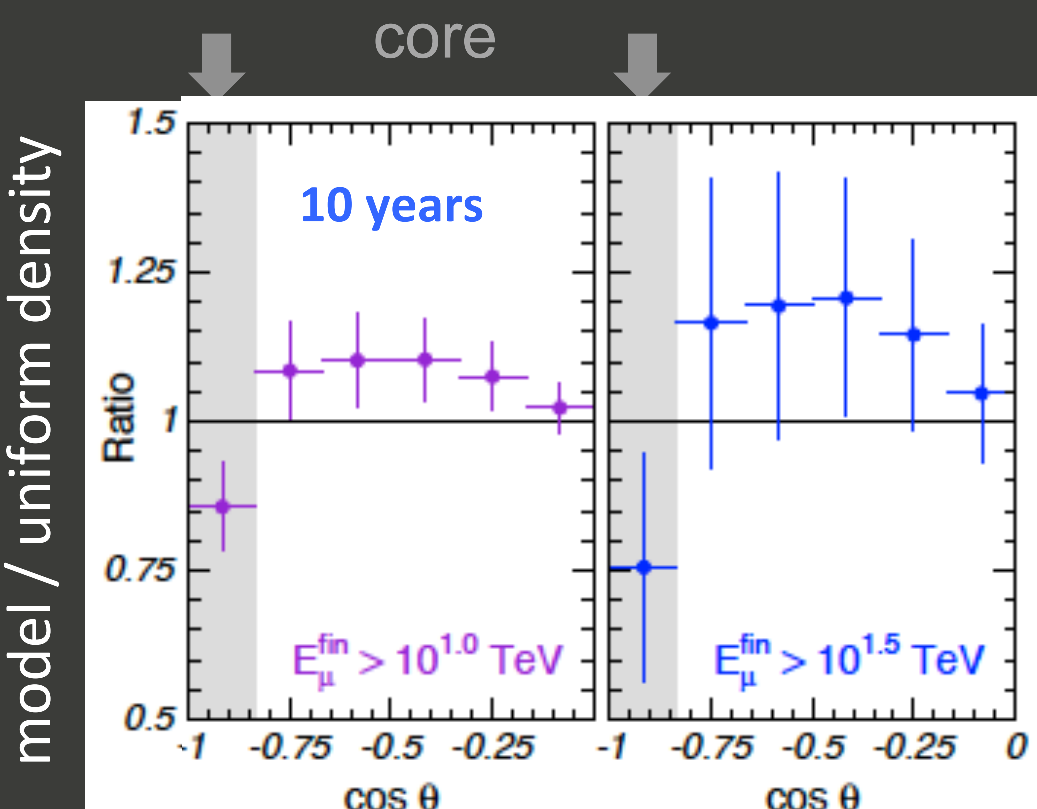


“Background” *(for neutrino astronomy)*
neutrinos produced by cosmic rays in the Atmosphere at the Antipodes

↓

“Signal”
for Neutrino Radiography of the Earth !

Direct measurement of Earth's core matter density from absorption of atmospheric neutrinos of very high energy (larger cross-section)



Calculations with current model (PREM) for IceCube, showing detectable deviation with respect to uniform density

Radiography of the Earth' core and mantle with Atmospheric neutrinos

(Gonzalez-Garcia et al., Phys. Rev. Lett. 2008)

A challenge/dream: Earth's core average chemical composition from neutrino oscillation?

An application of neutrino oscillations: Study of the Earth's core composition using atmospheric neutrinos
(A. Taketa, H.K.M. Tanaka and C. Rott, 3rd Hyper-Kamiokande Meeting, 21-22 June 2013)

Atoms have electrons and not muons
→ electron neutrinos have additional interactions in matter

Neutrino oscillation in matter depends of electron density

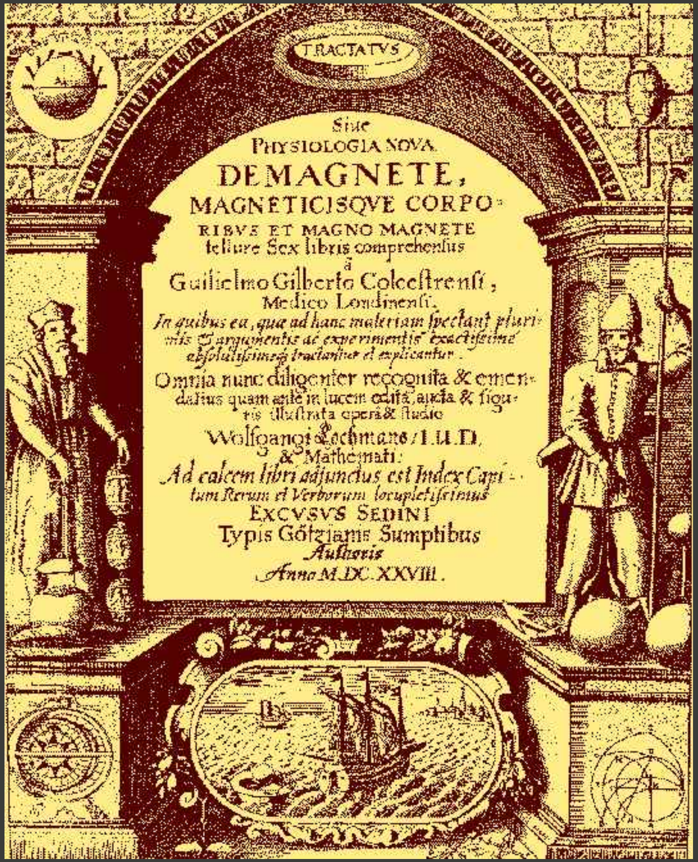
↓

Average chemical (Z/A) composition

by combining matter (conventIonal meas. and neutrinos) and electron density data

A great mystery of Earth's Science

Mostly Fe for generation of geomagnetic field?
(Gilbert 1600: permanent magnet; Elsasser 1946: dynamo)
………… ?



ABSTRACT

Why basic Science?

The visible driving force is the desire for knowledge that characterizes the human species and has led to our way of living in this World

What muons and neutrinos can do for Earth studies provides a beautiful example of a much broader motivation and shows the richness of Science as a whole

The spirit of this talk as from its abstract was ….

Why basic Science?

An answer through “Muon and neutrinos for Earth studies”

NIHONBASHI BRIDGE AT EDO TOWARD TOKKAIDO ROAD AND MT. FUJI (1863)

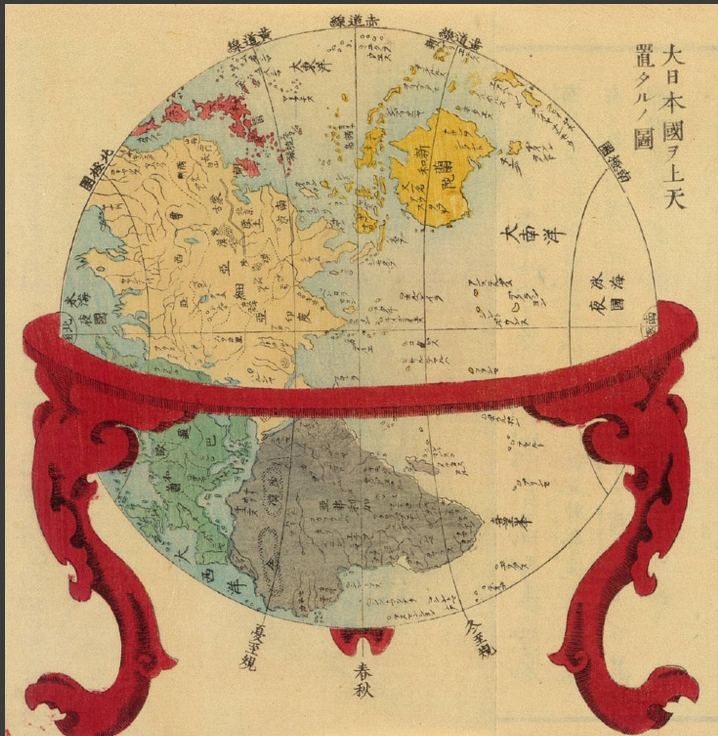
Utagawa Sadahide - Near end of Tokugawa period (1603-1868)

Even more fundamental questions

Why Science specially now?
What can scientists do for Science Education?

A project: “Science and School”

The World scenario is changing



Hashimoto Gyokuran (between 1856 and 1868)

http://assemblyman-eph.blogspot.it/2009/07/japanese-historical-world-maps.html

Western cartography in the traditional woodprint style: Image of a changing scenario

***New countries* strongly emerging**

For a number of "old" countries:

Economic hence social difficulties

Expensive manpower

Emigration of industrial production

To remain among leading countries in a changing World

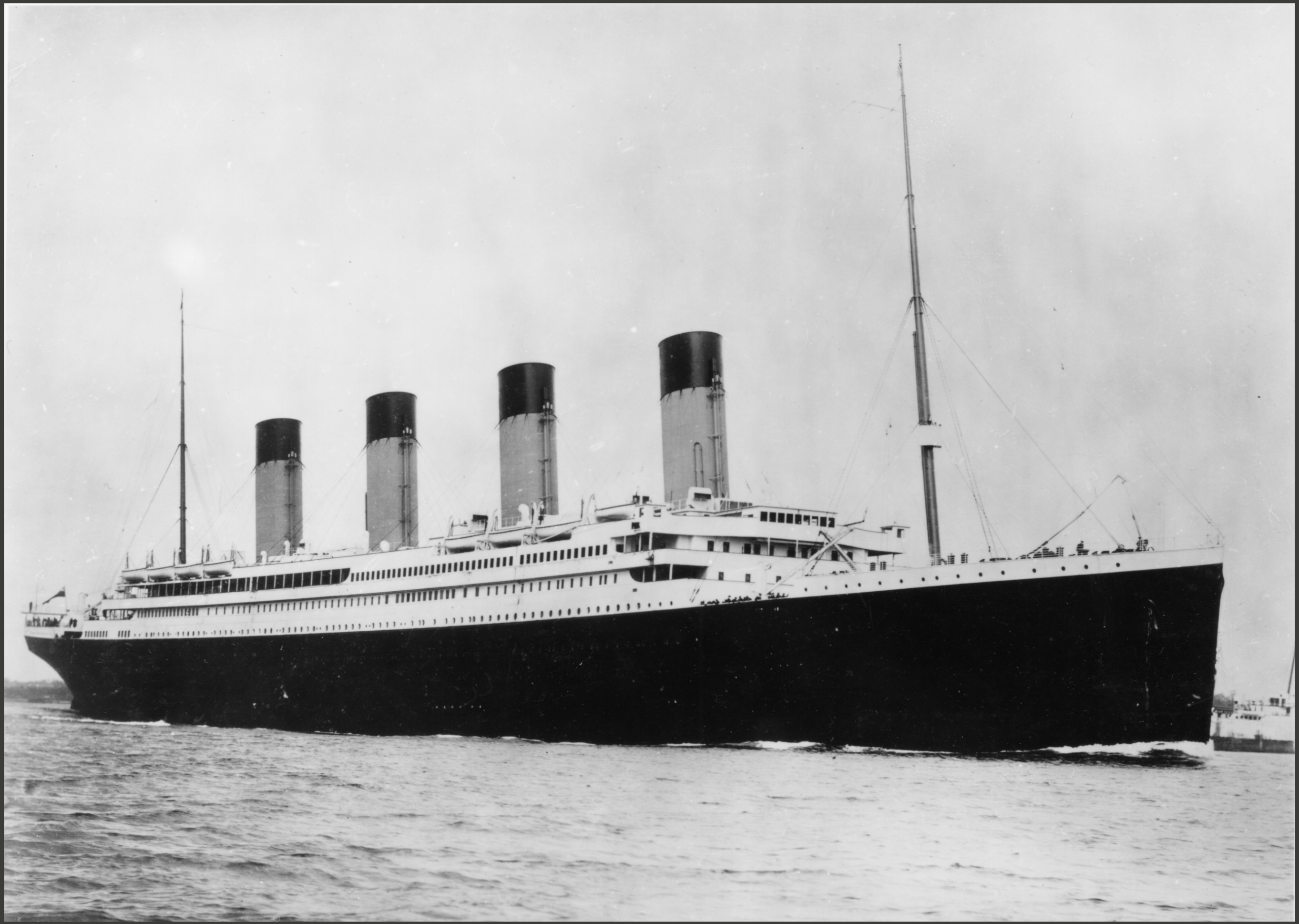
Science and Technology:
THE resource of “old” countries

↓

Invest in Education

Which view of Education ?

Is the concept of separate educational compartments still appropriate?



Titanic (1912)

Designed to be unsinkable thanks to watertight compartments

The emerging vision of Education

- *The quality of the educational process comes from all stages: global care*
- *Inquiry Based Science Education (IBSE): "learning by doing" already at Primary School*
- *High School students must be trained in research: may need support*
- *Learn at School basics of modern Science: may need updating teachers' knowledge*
- *Train High School students to communication and international life*

Support by university/research scientists is important

Future Science depends of quality/quantity of Education

No separate compartments

"Science and School"

An educational project open to collaboration
Students, teacher and researchers on the same floor

Experiments at School

Experience in research Labs

Visit research Labs

Discussion Forum

Thematic essays

Training for Olympics

Ask an expert

Science and Humanities

- Main Website: English + Italian
- Quasi-mirror Website: Japanese
- international experience:
  SKYSEF Forum @ Shizuoka Kita High School

SCIENCE and SCHOOL - SCIENZA e SCUOLA

科学と学校

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Youlaurea
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unisciti a noi

Mi piace 315

Siti amici (pagina con link)

SCUOLE SUPERIORI
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Comenio (Napoli)
Di Giacomo (S. Seb. Vesuvio)
Don Milani (Gragnano)
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Simmetrie: dai solidi platonici...

Scoop.it!

http://scienzaescuola.fisica.unina.it/

“The mind is not a vessel to be filled, but wood that needs igniting”

Plutarch (ca. 46-127 aC)

On listening to lectures