Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

U02-P01 Room:Poster Time:April 28 18:15-19:30

Review of the recent muon radiography observations by using nuclear emulsion detector

MIYAMOTO, Seigo[1*]

[1]The University of Tokyo

Nuclear emulsion is one of three dimensional particle tracker which have micron position resolution and the feature that no electricity so we can put this detector everywhere easily and also this is suitable for non-fixed point observation.

Several observations for volcanoes were done and will be done from 2011 to 2014. The imaging the of Unzen lava dome, which was formed from 1991 to 1995, was done by Miyamoto et al and they found the detector got many back ground particles and the amount is more than several times than expected muon signal. this implies that we are on the stage of background particle study.

The emulsion cloud chamber (ECC) is a modular structure made of a sandwich of passive material plates such as lead interleaved with emulsion film layers. Nishiyama et al studied the source of background noise in cosmic-ray muon radiography using ECC. They found that the origin of background is expected to be electromagnetic components of air-showers or cosmic-ray muons scattered in topographic material whith momentums is less than 2GeV/c.

The shallow conduit shape of Stromboli will provide the important information for eruption dynamics modeling by Tioukov et al. Hernandez et al put the emulsion detector near the top of summit of Teide volcano to investigate the past eruption histroy of Teide. Teide volcano is located in Teferife, Canary Islands, Spain. They are also under observation of the fault appeared in La Palma, Canary Island, in 1949, which is the sign of huge land collapse or not. The width of the fault is expected to be 1 meter or less, so high position resolution of emulsion detector is suitable for this observation. They will measure the width, delth and the porosity of this fault.

U02-P02 Room:Poster Time:April 28 18:15-19:30

Simultaneous inversion of muon radiography and gravity anomaly data for 3-D density structural analysis of lava domes

NISHIYAMA, Ryuichi[1*] ; MIYAMOTO, Seigo[1] ; OSHIMA, Hiromitsu[2] ; OKUBO, Shuhei[1] ; TANAKA, Hiroyuki[1]

[1]Earthquake Research Institute, University of Tokyo, [2]Usu Volcano Observatory, Hokkaido University

Cosmic-ray muon radiography (muography) has been utilized for obtaining the density profiles of volcanoes (eg. Tanaka et al., 2007; Lesparre et al., 2010; Câ̂rloganu et al., 2013). Since gravity measurement is also sensitive to the internal density of the Earth, a combination of muography and gravimetry is expected to provide density profiles with fine resolutions (Okubo and Tanaka, 2012). Nishiyama et al. (2014) has developed a simultaneous inversion method of both two data for determining the 3-D density structures of volcanoes and has presented the feasibility of the hybrid measurement through a case study of a small (500 m in diameter) lava dome, Showa-Shinzan, Hokkaido, Japan. This study revealed that a vent extends downward beneath the dome.

We are now planning another hybrid measurement at Tarumai Lava Dome on the Shikotsu caldera, Hokkaido, Japan, in order to perform a comparative study on the internal structures of lava domes. The Tarumai lava dome has formed at the top of Mt. Tarumai during the 1909 eruption. We conducted gravity measurements at 23 stations spanning 1.5 km (NS) x 1.5 km (EW). We are preparing the muography detector for the coming measurement. We report the possible detector sites and the result of the resolution test of this new hybrid measurement.

References:
Tanaka et al., Earth Planet. Sci. Lett., 263, 104-113 (2007).
Lesparre et al., Geophys. J. Int., 183, 1348-61 (2010).
Câ̂rloganu et al., Geosci. Instrum. Method. Data Syst., 2, 55?60 (2013).
Nishiyama et al., J. Geophys. Res. Solid Earth, 119, doi:10.1002/2013JB010234 (2014, in press).

Keywords: cosmic-ray muon radiography, gravity anomaly, density, lava dome

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

U02-P03 Room:Poster Time:April 28 18:15-19:30

Introduction about test measurement of the muon detection system for monitoring a groundwater (With some observations)

SANNOMIYA, Akira[1*] ; TANAKA, Hiroyuki[2] ; SUENAGA, Hiroshi[3] ; SUZUKI, Kouichi[3]

[1]Electric Power Development Co., Ltd, [2]Earthquake Research Institute,U of Tokyo, [3]Central Research Institute of EPI

The technique to radiographically image the internal structure of gigantic objects by utilizing muon's significant penetration power (muography) enabled us to investigate the internal structure of volcanoes and the city foundation with higher spatial resolution than possible with the conventional techniques.

This observation technique is applicable to exploring a large-scale civil engineering structure, the internal state of a base rock, etc. However, feasibility of muographic application to monitoring inside the large-scale civil engineering structure has not confirmed yet. Therefore, we decided to carry out test measurements in order to explore the possibility of muography for monitoring groundwater levels.

We are currently investigating the response of the groundwater levels to major rainfall events in the landslide area. We selected this area as an observation area. The measurement was carried out from the inside of a scupper tunnel in the base rock. Our muon detection system consists of plastic scintillator, photomultipliers (PMTs), and a high voltage (HV) power supply.

The muography detector was installed to the observation site in August, 2012 and measurement was started on the same date.

The result will be compared with the independent measurement results of groundwater levels and soil resistivity in order to quantitatively assess the technological limit of muography.

So far, we obtained the preliminary result that showed variations in the penetrating muon intensity; hence the density as a response of major rain fall events by plotting a moving average of the 48-hour observation time at different time intervals of one hour, two hours, three hours, and six hours. It showed a clear rainfall effect when the time interval is 6 hours. The future prospect includes further case studies for different rainfall-underground water coupling scenarios.

Keywords: muography, muon detection system, groundwater, test measurement, landslide

U02-P04 Room:Poster Time:April 28 18:15-19:30

A Historical View on the Degradation on Seismic Performance of The Parthenon, Greece and Muography as the Potential Eval

AOKI, Shimpei[1*] ; TANAKA, Hiroyuki[2] ; OHSHIRO, Michinori[3] ; YAMASHITA, Maria[4]

[1]Faculty of Letters, Kansai University, [2]Earthquake Research Institute, the University of Tokyo, [3]Faculty of Letters, Komazawa University, [4]Graduate Division of Arts and Sciences, Komazawa University

To reinforce the Parthenon against earthquakes, the process of disassembling and reassembling Doric columns is obligatory. For this, the column strength and durability is required to withstand the reconstruction process. Wooden rods in the dowels of each drum provide the mechanical strength of each column, however some of these rods may have been damaged during the Venetian bombardment of the Acropolis on September 26, 1687. Due to the size of the Parthenon's Doric columns, muography is more appropriate to image the internal structure than conventional radiographic techniques. Muography may be utilized as a non-destructive technique targeting the inside composition of the Parthenon's Doric columns, potentially providing the following information: (1) the durability of the columns against future earthquakes, and (2) the magnitude of the internal damage sustained during the Venetian bombardment. The results of this muographic survey would aid conservator's efforts to protect the Parthenon along with the possibly of applying to other cultural properties. Secondly, the state of the wooden rod inside the column will provide evidence for the time and temperature around the column (based on the geometrical structure and thermal conductivity of the column) which would contribute further evidence to historical discussions particular to the Parthenon, such as estimates of the amount of gun powder stored in the Parthenon by the Ottoman Empire and information on the aforementioned siege. Muography may supplement efforts to preserve and protect the Parthenon as well as contributing to our understanding of the historical events that have occurred in this ancient structure.

Keywords: a Historical View, the Degradation on Seismic Performance, the Parthenon, Muography

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

U02-P05 Room:Poster Time:April 28 18:15-19:30

Geo-neutrinos and reactor anti-neutrinos expected in Daya Bay II and in LENA

BALDONCINI, Marica[1*] ; ESPOSITO, Juan[2] ; LUDHOVA, Livia[3] ; MANTOVANI, Fabio[1] ; RICCI, Barbara[1] ; XHIXHA, Gerti[1] ; ZAVATARELLI, Sandra[4]

[1]University of Ferrara, [2]INFN, Legnaro National Laboratories, [3]University of Milan, [4]University of Genova

Geo-neutrinos produced by beta decays occurring in ^{238}U and ^{232}Th decay chains are presently detected via inverse beta reaction in liquid scintillation detectors (KamLAND and Borexino). Geo-neutrinos are a unique direct probe of our planet's interior since they instantaneously bring to the Earth's surface information concerning the total amount and distribution of U and Th in the crust and in the mantle, which are thought to be the main reservoirs of these elements. The geo-neutrino spectrum allows to discriminate the different Th and U components. Measuring geo-neutrino fluxes and spectra can shed light on the radiogenic contribution to the terrestrial heat power and on the Earth's nowadays composition, providing a direct test of the Bulk Silicate Earth models and giving additional constraints on the Earth's evolution models.

A better discrimination among different Earth's global models can be reached combining the results from several sites: new measurements of geo-neutrino fluxes are highly awaited from experiments entering operation, such as SNO+, or proposed to the scientific community, as LENA or Daya Bay II. In particular, LENA and Daya Bay II would provide a substantial increase of the detection sensitivity and of the event rate thanks to their large target masses (50 kton and 20 kton, respectively) compared to the 1 kton mass of KamLAND and SNO+ and to the 0.3 kton of Borexino.

The main background in geo-neutrino measurements is due to the electron anti-neutrinos produced by nuclear power plants, which are the strongest man-made anti-neutrino sources. Many fission products decay through beta processes with the consequent emission of electron anti-neutrinos, the so called reactor anti-neutrinos. The reactor anti-neutrino spectrum covers an energy range extending up to about 8 MeV, which results in a significant overlap between geo-neutrino and reactor anti-neutrino signals in the geo-neutrino energy window ($1.8 - 3.3$ MeV). The events of reactor anti-neutrinos are strongly dependent on the distance of the closeby commercial nuclear power plants. Therefore, a careful analysis of the expected reactor anti-neutrino event rate at a given experimental site is mandatory.

In this framework, we estimate the expected reactor anti-neutrino signals at ongoing geo-neutrino experiments sites, in particular at Pyhasalmi and JUNO (Jiangmen Underground Neutrino Observatory), which are the candidate sites for hosting the LENA and Daya Bay II experiments, respectively. The inputs required to evaluate the reactor anti-neutrino flux come from neutrino properties, nuclear physics in the reactors and features of nuclear power plants. In our calculation we take into account the three neutrino oscillation mechanisms in vacuum, the most updated reactor anti-neutrino spectra and standard fuel compositions. According to the International Atomic Energy Agency (IAEA) database, we use detailed information on the locations and on the monthly time profiles of the thermal power for each nuclear core.

In Table 1 we report the expected geo-neutrino and reactor anti-neutrino signals for different locations, expressed in TNU (Terrestrial Neutrino Units). Nuclear power plants data refer to IAEA database reporting information of year 2012, when all of the Japanese nuclear power plants were still switched off. The ratio between the expected reactor anti-neutrino signal in the geo-neutrino energy window (R_G) and the expected geo-neutrino signal (G) is calculated all over the world in order to produce a R_G/G map. The values of R_G/G for future sites (Phyasalmi and JUNO) are almost comparable to the operating ones (LNGS and Kamioka), with a slight preference for the Finnish location. The total uncertainty on the reactor signal predictions is on the order of 5%: among all the accounted sources of uncertainties, the ones giving the main contributions originate from the θ_{12} mixing angle, the anti-neutrino spectrum, the fuel composition and the thermal power.

Keywords: geo-neutrino, anti-neutrino from reactor, neutrino detector

U02-P05 Room:Poster Time:April 28 18:15-19:30

Sites	R [TNU]	R_G [TNU]	G [TNU]	R_G/G
LNGS	85.8 ± 4.6	22.8 ± 1.1	$40.3^{+7.3}_{-5.8}$	0.6
KAMIOKA	70.1 ± 3.7	18.7 ± 1.1	$31.5^{+4.9}_{-4.1}$	0.6
SUDBURY	174.6 ± 9.0	43.1 ± 2.1	$45.4^{+7.5}_{-6.3}$	0.9
PHYASALMI	69.2 ± 3.7	17.5 ± 0.8	$45.3^{+7.0}_{-5.9}$	0.4
FREJUS	587.9 ± 31.0	134.0 ± 7.1	$42.4^{+7.6}_{-6.2}$	3.2
HOMESTAKE	27.7 ± 1.5	7.3 ± 0.3	$48.7^{+8.4}_{-6.9}$	0.1
HAWAII	3.4 ± 0.2	0.9 ± 0.04	$12.0^{+0.7}_{-0.6}$	0.1
CURACAO	9.5 ± 0.5	2.5 ± 0.1	$29.3^{+4.2}_{-3.3}$	0.1
JUNO	99.0 ± 5.1	27.4 ± 1.4	$39.7^{+6.5}_{-5.1}$	0.7

Table 1: Comparison between expected reactor (R) and geo (G) antineutrino signal. R_G indicates the reactor signal expected in the geo neutrino energy window ($E_{\bar{\nu}} < 3.26$ MeV). 1 TNU = 1event/year/10^{32} protons.

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

U02-P06 Room:Poster Time:April 28 18:15-19:30

Towards a refined regional geological model for predicting geoneutrinos flux at Sudbury Neutrino Observatory (SNO+)

STRATI, Virginia[1*] ; HUANG, Yu[2] ; MANTOVANI, Fabio[1] ; SHIREY, Steven B.[3] ; RUDNICK, Roberta L.[2] ; MCDONOUGH, William F.[2]

[1]University of Ferrara, [2]University of Maryland, [3]Carnegie Institution of Washington

The SNO+ detector is the redeployment of the illustrious Sudbury Neutrino Observatory (SNO) at SNOLAB in Ontario (Canada). After the substitution of heavy water (D_2O) with liquid scintillator (CH_2) inside the inner vessel, in 2014 the 1 kton detector will come on-line and together with KamLAND in Japan and Borexino in Italy will accumulate geoneutrino events. Geoneutrinos are electron antineutrinos originating from beta decays of natural radioactive nuclides in the Earth interior. A fraction of them, generated from ^{214}Bi and ^{234}Pa of ^{238}U decay chain and from ^{228}Ac and ^{212}Bi of ^{232}Th decay chain, are above the threshold for inverse beta reaction on free protons and can be detected by SNO+. Geoneutrinos are a real time probe of Earth interior, because the flux at the terrestrial surface depends on the amount and distributions of U and Th in the Earth's reservoirs. To extract global information such as terrestrial radiogenic heat power or to test compositional models of the Bulk Silicate Earth (BSE), the regional contribution to the geoneutrino signal has to be controlled by study of regional geology.

We present the 3-D refined geological model of the main reservoirs of U and Th in the regional crust extended for approximately 2×10^5 km^2 around SNOLAB, including estimates of the volumes and masses of Upper, Middle and Lower crust, together with their uncertainties. According to the existing global reference model (Huang et al., 2013), this portion of the crust contributes for 43% of the total expected signal at SNO+. The remaining contributions come from the far field crust (34%), from continental lithospheric mantle (5%) and from the mantle (18%). Since SNO+ will accumulate statistically significant amounts of geoneutrino data in the coming years, the calculated signal that is predicted to be derived from the lithosphere can be subtracted from the experimentally determined total geoneutrino signal to estimate the mantle contribution.

The main crustal reservoirs are modeled by identifying three main surfaces: the Moho discontinuity, the top of the Lower Crust and the top of the Middle Crust. About 400 depth-controlling data points obtained from deep crustal refraction surveys and from teleseismic receivers are the inputs for the spatial interpolation performed with the Ordinary Kriging estimator. This method takes into account the spatial continuity of the depths and it provides the uncertainties of the crustal volumes. The Upper Crust is further modeled in detail combining information from vertical crustal cross sections and Geological Map of North America at 1:5,000,000 scale. Seven sub-reservoirs with distinctive characteristics lithologies, metamorphism, tectonic events and chemical composition are identified. The density and the abundances of U and Th in the seven sub-reservoirs are evaluated from the published litho-geochemical databases, including analyses of representative outcrop samples. The Middle and Lower Crust densities and radioactivity contents are evaluated from seismic constraints.

The numerical 3D model consists of about 9×10^8 cells of 1 km $\times$ 1 km $\times$ 0.1 km dimensions. For each of them geophysical information, such as latitude, longitude, depth and reservoir type, are combined with estimates of the U and Th abundances to predict the geoneutrino signal at SNO+ originated from the regional crust. The total geoneutrino signal at SNO+ is about 12% less than that calculated using the global reference model (Huang et al., 2013).

Keywords: geoneutrinos, SNO+, uranium, thorium, geological modeling

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

U02-P07 Room:Poster Time:April 28 18:15-19:30

Upgrade plan of the KamLAND detector for improvement of sensitivity to geo-neutrino

OBARA, Shuhei[1*]

[1]RCNS, Tohoku University

Neutrino, which is a kind of elementary particles, interacts with other particles only via weak interaction. RCNS, Tohoku University, researches the neutrino science with the large neutrino detector, KamLAND. Measuring the geo-neutrinos that are produced in beta decays within the Earth′ s interior, is only way to estimate the Earth′ s radiogenic heats production and constrain composition models of the Earth.

The KamLAND detector is marked by the ability to detect low energy electron-type anti-neutrinos. Radioactive isotopes, such as ^{238}U and ^{232}Th decay as follows, and produce the electron-type (anti-) neutrinos (geo-neutrino).

^{238}U→ ^{206}Pb+8 ^{4}He+6e^{-}+6$\nu^{bar}{}_{e}$+51.7[MeV]

^{232}Th→ ^{208}Pb+6^{4}He+4e^{-}+4$\nu^{bar}{}_{e}$+42.7[MeV]

Geo-neutrino flux directly informs us the radiogenic heat generation. In fact, previously, the KamLAND experiment has given the result; the radiogenic heat production in the Earth′ s interior by ^{238}U and ^{232}Th is estimated to be $20.1_{-9.1}{}^{+9.1}$ TW through measuring the geo-neutrinos, and it is obviously smaller than the Earth′ s total heat flow (44 $\pm$ 1TW).

In order to improve the sensitivity of the KamLAND detector, the upgrade plans (KamLAND2 experiment) are in progress. Large light intensity liquid scintillator, light collection mirror, high quantum efficiency photomultiplier, imaging device, scintillation film, etc...

In the KamLAND2 experiment, improving energy and vertex resolution are expected. Therefore it will be possible to observe geo-neutrinos with higher accuracy and statistics. This experimental improvement will have higher ability to discriminate between models and separate contributions from ^{238}U and ^{232}Th. The KamLAND2 will play a contribution to the geo physics in that way.

In this presentation, future prospects and R&D are discussed.

Keywords: geo-neutrino

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

U02-P08 Room:Poster Time:April 28 18:15-19:30

The next-generation KamLAND electronics

HAYASHIDA, Shingo[1*]

[1]Research Center for Neutrino Science, Tohoku University

KamLAND was constructed to detect the low energy anti-neutrinos. And then, KamLAND detected reactor neutrinos and solved solar neutrino problem on 2003. And furthermore, KamLAND detected geo-neutrinos for the first time in the world on 2005. Currently, KamLAND has already been beginning to search several new physics. However, searching new physics in the detector of 10 years ago is difficult. So, it is necessary to update the detector. We are planning to update the KamLAND. As this updating, KamLAND electronics will be renewed using the latest technologies. The next-generation KamLAND electronics will certainly contribute to geoscience.

Keywords: Neutrino detector, Data taking, electronics

U02-P09 Room:Poster Time:April 28 18:15-19:30

Imaging detector

MITSUI, Tadao[1*]

[1]RCNS, Tohoku University

Geo-neutrinos are emitted from radioactive elements, such as Uranium and Thorium, in the Earth's interior. Those elements contribute about one half of Earth's heat source. With high transmissivity of neutrinos, geo-neutrino may enable us to measure heat sources in the deep mantle. Since 1-kton liquid scintillator detector "KamLAND" detected geo-neutrinos in 2005, it has been expected as a new probe of Earth's interior. At present, an Italian detector "Borexino" is also observing geo-neutrinos, realizing a "stereo observation". However, observation points are still not enough. In addition, lack of the directional information of geo-neutrinos are serious disadvantage in making the data more precise. We are now developing a new detector for directional measurement of geo-neutrinos, aiming at installing it in KamLAND in the near future. Geo-neutrinos are electron antineutrinos being detected with an inverse beta decay channel with a free proton. Directional information of the neutron, emitted in the inverse beta decay channel, should be measured, in order to measure the direction of the incoming electron antineutrino. To this purpose, we are developing liquid scintillators doped with Lithium-6, which has large neutron capture cross section, and imaging detectors, which detect the vertex position of neutron capture precisely. In this poster, imaging detectors, that we are developing, are reviewed. To detect feeble light emission of the scintillator (actually one photon level), and determine the emission position precisely, optics with large acceptance and small aberration, together with a light detector with high quantum efficiency and positional sensitivity should be employed. In our current R&D, a hopeful design is that with a mirror of diameter 50 cm, and a 256-channel multi-anode photomultiplier tube. Highlighting that design, we will review the latest progress, plan of installing it, expected geophysical results.

Keywords: neutrino, geo-neutrino, radiogenic heat source

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

U02-P10 Room:Poster Time:April 28 18:15-19:30

Li loaded liquid scintillator for directional measurement

SHIRAHATA, Yutaka[1*]

[1]RCNS, Tohoku University

By the detection of the electron antineutrino using the current liquid scintillator, we can suppress the large background by the delayed coincidence of positron and neutron released by the inverse β-decay that proton and electron antineutrino cause. And we can observe electron antineutrino in the low energy scale.

On the other hand, we cannot know the coming direction of the electron antineutrino like the water Cerenkov method with the existing detector.But we can know the coming direction of the electron antineutrino by observing both reaction point of positron and capture point of neutron.If we could observe the coming direction of the electron antineutrino in the low energy scale, we would distinguish a neutrino every observation object and be able to expect observation with high precision.

There are three necessary conditions to detect the coming direction of the electron antineutrino by a liquid scintillator; (i)capture a neutron before losing directional information, (ii)cause luminous phenomenon at a neutron capture point, (iii)develop a new detection technology with the high position identification performance to detect the reaction points.

In current liquid scintillator, it takes about 200μs until a positron captures a thermal neutron released by inverse β-decay and this reaction emits 2.2MeV gamma ray. The released thermal neutron scatters about 10 cm, and so the neutron loses antineutrino ′ s directional information. The neutron produces 2.2MeV capture gamma ray and it obscures the neutron capture point. To solve this problem, we developed ^{6}Li loaded liquid scintillator. ^{6}Li has large neutron capture cross section (940barn) and when ^{6}Li captures neutron, it releases alpha ray that it cannot move a long distance in the liquid scintillator. We can expect to solve two problems by using this new liquid scintillator and also to detect the coming direction of the electron antineutrino using imaging detector that has high position resolution.

In presentation, I will talk about the lithium loaded liquid scintillator developed by an original method.

Keywords: geo-neutrino

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

U02-P11 Room:Poster Time:April 28 18:15-19:30

Tomography of the earth with large-scale neutrino experiments

HOSHINA, Kotoyo[1*]

[1]Earthquake Research Institute, the University of Tokyo, [2]Wisconsin IceCube Particle Astrophysics Center

Experimental techniques to study inside of the Earth have been developing remarkably in the past decades. For example, in-situ x-ray diffraction measurements under high-pressure and high-temperature opened new era for studying about possible chemical components and structures of deep Earth. In the next ten years, we will obtain yet another technique for direct measurements of the Earth's interior.

Probing inner structures of the Earth with neutrinos has been discussed for more than 30 years. Neutrinos are chargeless particles and have very small cross-sections. They normally penetrate the Earth without any interaction, and from the rare interactions that do occur we obtain information on the density profile of the Earth's interior. However, the elusive characteristic of neutrinos poses a challenge for detecting them at experimental sites. To compensate for the small interaction cross-section, one needs a large volume neutrino detector.

The IceCube[1] neutrino observatory, completed in 2011 and has 1 cubic kilo-meter volume of detector size, is a possible candidate for this study. Current status of a study for measuring the core density of the Earth with atmospheric neutrino will be presented.

Another characteristic of neutrino is that they change their flavor periodically (neutrino oscillation). These oscillation patterns are affected by the density profile of electrons along the path of the neutrino. Comparisons between the Earth's mass-density profile and the electron-density profile give us ratio profiles of atomic number vs mass number (A/Z), which contains information of chemical composition of the Earth.

It is crucial to use a specific energy range for source neutrinos in order to perform the neutrino oscillation tomography. For Earth's core, the energy range is ~1GeV to 30GeV. To detect the GeV-range neutrinos with sufficient statistics, next-generation experiments Hyper Kamiokande[2] and PINGU[3] have been proposed. Possible discrimination powers of some chemical models of the Earths core will be discussed.

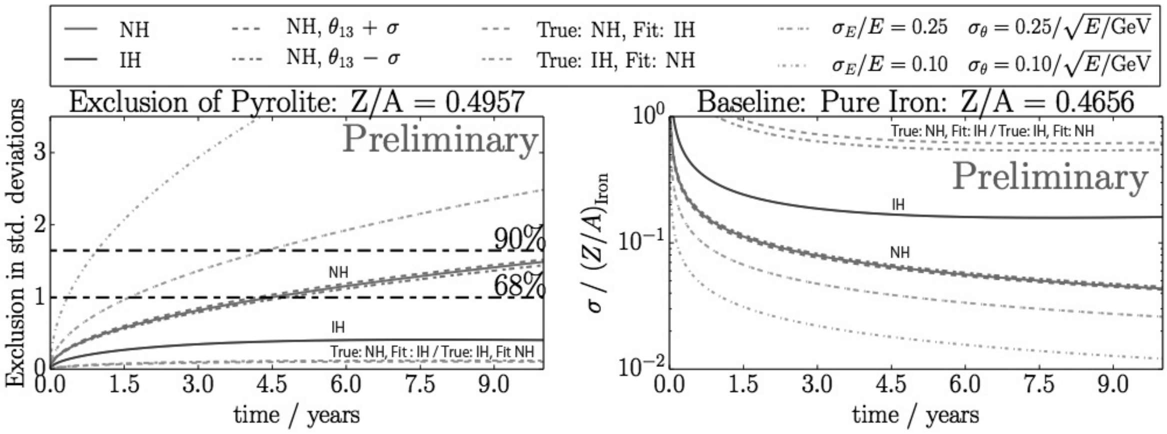
Fig.1
Left: Exclusion of a pyrolite core model with respect to a pure iron core a time range of ten years. Right: The accuracy, measured in units of sigma, of the Z/A measurement for the assumption of an iron core. Calculated for PINGU[3].

References

1.IceCube Collaboration, Astroparticle Physics 26, 155(2006)
2.LoI: The Hyper-Kamiokande experiment, arXiv:1109.3262(2011)
3.LoI: The Precision IceCube Next Generation Upgrade, arXiv:1401.2046 (2014)

Keywords: neutrino tomography, neutrino radiography, IceCube

U02-P11 Room:Poster Time:April 28 18:15-19:30



Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

U02-P12 Room:Poster Time:April 28 18:15-19:30

Muographic imaging of Usu volcano with a multilayer detector

KUSAGAYA, Taro[1*] ; TANAKA, Hiroyuki[1] ; OSHIMA, Hiromitsu[2] ; MAEKAWA, Tokumitsu[2] ; YOKOYAMA, Izumi[3]

[1]Earthquake Research Institute, University of Tokyo, [2]Graduate School of Sciences, Hokkaido University, [3]The Japan Academy

Usu volcano is one of the most active volcanoes in Japan and has erupted for four times in the recent 100 years (1910, 1943, 1977-1978 and 2000). In the 1977-1978 eruption, 18 craterlets and a U-shaped fault were formed in the summit crater. The eruption also caused the deformation in the summit crater area with a diameter of 1.8 km and formed an upheaval called Usu-Shinzan.

Preceding studies suggested that the cooling magma intrusion with a height of 600 m and a width of 300 m was located below the Usu-Shinzan by magnetotelluric soundings (e.g. Ogawa et al., 1998, Matsushima et al., 2001). And Yokoyama and Seino (2000) built a tilt model to interpret the formation of Usu-Shinzan. In this model, a block with a width of 800 m tilted approximately 11^o on a pivot at a depth of 800 m. So, in the present work, we conducted the muographic imaging (radiography with cosmic-ray muon) of Usu volcano to confirm the existence of magma intrusion beneath Usu-Shinzan.

But there is the issue of background (BG) noise of muographic imaging for a large volcano ($>$1 km thick). Since the integrated intensity of traversing cosmic-ray muons steeply decays as a function of the thickness of the target, the signal-to-noise (S/N) ratio also decreases seriously as the size of target becomes larger, and thus the density distribution cannot be accurately measured at a large volcano. The background (BG) noise that reduces the S/N ratio mainly consists of the fake tracks that are generated by the accidental coincidence of the electromagnetic (EM) shower particles. The values of BG noise were 10^{-6} cm^{-2} sr^{-1} s^{-1} (Lesparre et al., 2012) and 10^{-7} cm^{-2} sr^{-1} s^{-1} (Carloganu et al., 2013). BG noise of 10^{-7} cm^{-2} sr^{-1} s^{-1} corresponds to integrated cosmic-ray muon intensity after traversing 1 km of 2.65-g cm^{-3} rock.

In order to solve this problem, we developed a novel muon detection system that consists of multiple layers of position sensitive detectors (PSDs) in conjunction with a trajectory analysis method to effectively reduce the BG noise. In this method, the EM shower-originated fake tracks are rejected by requesting a linear trajectory for a muon event (linear cut method) since EM shower particles randomly hit each PSD layer and make a non-linear trajectory in the detection system. This detection system was applied to Usu volcano, Hokkaido, Japan to image its internal density structure (the spatial distribution of the density). In this measurement, we utilized a muon detection system that consisted of 7 layers of PSDs. One PSD consisted of x- and y- arrays of plastic scintillator strips with an active area of 1.21 m^2 and a segmented area of 10x10 cm^2. The angular resolution was +/- 3^o. The measurement duration was 1977 hours (82 days).

In this measurement, we compared the integrated cosmic-ray muon intensity traversing 2500 m of 1.5-g cm^{-3} rock with observed data at an elevation angle of 55.6 mrad. Assuming that the residual between the calculated intensity and data is BG noise, we obtained the BG noises of 5.4x10^{-5} cm^{-2} sr^{-1} s^{-1} with two PSDs and 1.9x10^{-6} cm^{-2} sr^{-1} s^{-1} with seven PSDs. The multilayered muon detector was effective to reduce the BG noise. However, BG noise remains and they may be attributed to another source of BG noise such as upward-going particles(Jourde et al., 2013). This measurement yielded the following results: (A) by analyzing the region that has a thickness of more than 1000 m, we confirmed that our detection system is sensitive to a density variation of 10% in 1300-m rock; and (B) there are high- and low-density anomalies beneath between Oo-Usu and Usu-Shinzan peaks, which is consistent with the magma intrusion and the resultant fault generation suggested by Yokoyama and Seino (2000), Ogawa et al. (1998) and Matsushima et al. (2001).

For the future prospect, we will try to use the shield in order to distinguish the upward-going particles from muons arriving from a volcano side.

Keywords: muography, muon, radiography