Progress Report September-October 2004

5 November 2004.

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This document presents an overview of the essential events related to the Earth AntineutRino TomograpHy (EARTH) programme in the period September-October, 2004. This is the second progress report: the first one covered the period May-August 2004.

Funding

With the startup funding by ASTRON and the matching in manpower by the KVI, the programme has been declared started on 1 September 2004. Several attempts to obtain a written confirmation from the South African National Research Foundation (NRF) have not yet been obtained, but in practice the people at iThemba LABS and the University of Cape Town (UCT) are working on the programme as agreed.

On 21 September 2004 separate meetings took place with Dr. H. Chang, director of the Dutch funding agency for physics research FOM, en dr. S.K. Kuipers, chairman of the Board of the Rijksuniversiteit Groningen.

In the meeting with Dr. Chang we asked for help and advice from FOM to realise EARTH. It is well-known that the present financial situation of FOM prohibits a direct support by FOM. As a first step dr. Chang proposes that he will mention EARTH in his meeting with the FOM board. He will ask the board members to invite the EARTH-team to present the proposal to them at their institutes.

In the meeting with Dr. Kuipers he states that the Board of the Rijksuniversiteit Groningen in principle has a positive attitude towards EARTH, but is somewhat concerned about the use of the location of Curaçao.

Curaçao

Ad van den Berg and Rob de Meijer met prime minister Ys of the Dutch Antilles, and the minister plenipotentiary, Mr Comenencia at the Antillenhuis, The Hague, on 2 September. After a presentation of the programme and the potential benefits for Curaçao, a discussion takes place on the potential of the programme for Antillean industry and the possibilities to start education of potential employees at a Curaçao laboratory. One of the suggestions is to establish per year three bursaries for which high-school students can compete and that will allow them to study physics at the University in Groningen with special supervision of the KVI. The possibilities have to be explored to find the needed funding: for example one scholarship by the Antillean government, one by the Rijksuniversiteit Groningen and one from a private organisation. The private organisation has responded positively.

The Antillean government invites members of the EARTH-team to visit Curaçao. Together with Mr Comenencia we are preparing a visit to Curaçao in the first week of January. During the visit we like to get in contact with the authorities, industries and especially contacts with the Technical Faculty of the university of the Netherlands Antilles and a couple of high schools. Moreover we like to visit a possible site for the antenna. As part of the preparations of the visit Emiel van der Graaf collects information on the (deep) geology of Curaçao. For this purpose we met with geologist prof. em. Beets on 14 October.

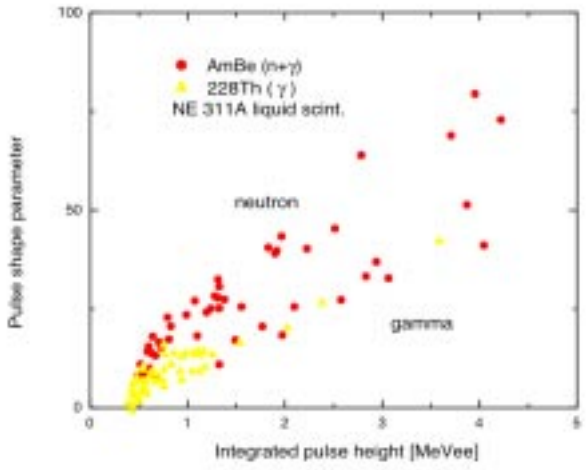
Industrial partners
From a very early stage on Focus Oil and Gas has been connected to EARTH. In Groningen Technology Centre Northern Netherlands (TCNN) has been active in attracting industry to the programme. TCNN and the Dutch drilling consulting firm, FOCUS OIL and Gas, prepare a proposal for a feasibility study on the required drilling technology. In this framework KVI will prepare an overview of information available on the (deeper) geology of Curaçao.

On 30 September a meeting, organised by TCNN, took place between a number of representatives of industries in the northern part of The Netherlands. The aim of the meeting is to extend the participation of industrial partners in the EARTH especially in the first phase of EARTH. The meeting was organised by TCNN in collaboration with KVI.

After an introduction of the people around the table, Rob de Meijer (EARTH/KVI) gives a more general overview of the aim, the plans and the technological challenges of the programme EARTH. Next Heinrich Wörtche (EARTH/KVI) describes the various challenges in more detail. The presentations are interrupted several times by participants asking questions. A lively discussion starts afterwards. From a round along the table it becomes clear that all participants consider the project from technological point of view feasible. It becomes clear that the operating temperature is a crucial condition for the feasibility of a working detector and that it should be kept as low as possible. For the further development we aim at a maximum temperature of 50ºC. Because of a lackof information the question at which depth this temperature is reached in Curaçao has to be left open. Moreover it has to be seen if the layer of the overlaying rock will be sufficient for the shielding against muons.

TCNN represented by Patrick Cnubben gives an overview for funding of the work by the companies. He identifies five possible topics for feasibility studies performed in collaboration with industry: scintillator material, photo detectors, electronics, power supplies (heat exchanger & detector cooling), detector housing. TCNN, represented by Arno Gielen, contacted the participants to find out that five companies will join Focus Oil and Gas, Beverwijk in the EARTH Industrial Consortium. TCNN is preparing a consortium agreement. The partners are listed at the end of this document.

Detector development
The South-African team has experimentally simulated antineutrino detection by using an existing test cell to investigate the feasibility of delayed neutron detection and particle identification based on pulse-shape discrimination. The cell is filled with a liquid scintillator doped with B. Digital scopes with a variety of bandwidths are used to determine where the limit is of information to be gained out of the pulses. Pulse characteristics useful for pulse shape discrimination have been

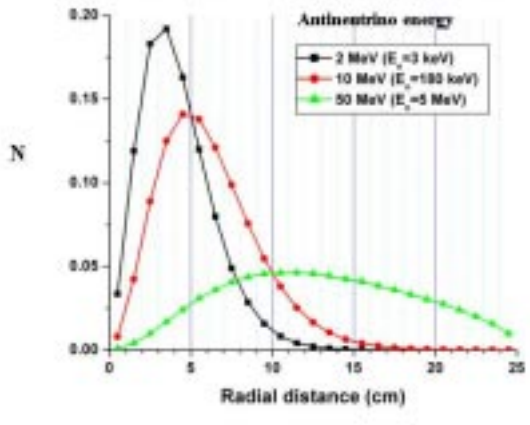


investigated. A start has been made using a double photomultiplier tube setup on a NE213 scintillator to look at the sensitivity of the correlation of pulse height and distance from the tube face.

In experiments with an AmBe source producing both neutrons and gamma rays and a ^{228} Th source, only producing gamma rays, they investigated pulse-shape discrimination. Preliminary data are presented in the figure. It shows the variation of the pulse-shape parameter with integrated pulse height for neutrons and gamma-rays. The neutrons are detected via recoil protons.

In South Africa two routes are being followed in simulations. The quick approach is using a Python programme to visualise results from kinematic calculations as a useful tool to determining an optimum size and shape of the detector. For this a Monte Carlo programme to simulate the operation of the proposed antineutrino detector was written. The first calculations were made and the results of the simulations are consistent with those presented in the references quoted. In the more thorough and time-consuming route, the problem is being defined with MCNP-X to help verify the optimum detector parameters.

In Groningen Monte Carlo simulations are being used to start investiging the feasibility of directional sensitivity for antineutrino detection. One of the first obstacles to be surmounted is the fact that standard models such as coded in MNCP do not treat interactions between antineutrinos and matter. The latest version of MCNP-X, fortunately, allows simulating correlated emission of particles. Initially the kinematics of the antineutrino capture and its subsequent emission of a positron-neutron pair was investigated for several energies in the range of 2 MeV (geo-antineutrinos) to 50 MeV (supernova antineutrinos). In a paper Beacom and Vogel give the basis for the kinematics. The calculations confirm that the positron has hardly any directional emission preference but contains the energy information of the captured antineutrino. The neutron energy is small, but it is preferentially emitted in the direction of the incoming antineutrino.



The figure shows the range distribution of the neutrons for a number of incoming antineutrino energies in a scintillator doped with Boron. It shows that the range of the neutrons depends on the energy of the antineutrinos. This information plays an important role in the design of the directional sensitive detector.

Scientific partners

In addition to South Africa, physicists at Münster, Germany, have already expressed interest in EARTH. The appointment of prof. Chr. Weinheimer by 1 October opens new avenues of

collaboration between physicists at Münster and at the KVI. Prof. Weinheimer is one of the leading scientists in the experiment KATRIN at Karlsruhe aiming at an accurate determination of the (anti)neutrino mass via beta-decay of tritium. A discussion took place on how to exchange participation: KVI participating in KATRIN, whereas Münster will like to continue to work with the KVI cyclotron AGOR and will participate in EARTH. The AGOR experiments are related to the nuclear matrix elements in double β-decay.

In view of the anticipated collaboration prof. Weinheimer gave a seminar at the KVI on 1 October, whereas prof. de Meijer gave a colloquium in Münster on 25 October. After the colloquium it was discussed how such collaboration could be extended to LOFAR and whether EU-funds could be tapped to provide finances for the collaboration efforts. At this time the possibilities are investigated from both sides.

Industrial applications
Emiel van der Graaf discussed at NRG-Petten, NL possible application of compact antineutrino detectors for monitoring nuclear power plants on 26 May. NRG is interested in collaboration. A meeting is set for 17 November 2004.

Seminars and presentations.
R.J. de Meijer, *Earth AntineutRino TomograpHy*, Antillenhuis, The Hague, 2 September 2004.
A.M. van den Berg, *Stand van zaken en vooruitzichten voor ASTRON-gerelateerde neutrino projecten*, KVI, Groningen, September 2004
A.M. van den Berg, *Bringing together two extremes in neutrino detection: from low to the highest energies*, 2nd Dutch Astroparticle physics meeting, 24 September 2004.
R.J. de Meijer, *Earth AntineutRino TomograpHy*, TCNN, 30 September 2004.
H.J. Wörtche, *Earth AntineutRino TomograpHy: Nuts and Bolts*, TCNN, 30 September 2004.
R.J. de Meijer, *Antineutrinos to explore Terra Incognita*, Colloquium, Physics Department, University of Münster, Germany, 25 October 2004.
M. Maucec, Monte Carlo simulations of neutron and positron distribution from inverse beta decay, Fall meeting Dutch Physical Society Meeting, Lunteren 29 October 2004.

Publications and publicity.

- In popular scientific journals articles appeared that mentioned the antineutrino antenna at Curaçao.:

Antilliaans Dagblad, *Antineutrino's*, 28 September 2004.

Website and ppt-mastersheet.
A beginning is made to have a web site. Initially it will be part of the KVI website. A document has been produced as basis. Moreover a logo has been designed.

For Power Point presentations a background sheet is available for members of the consortium.

Teams.
The Dutch team consists of:

- KVI:

Dr. A.M. van den Berg (0.25 fte)
Dr. E.R. van der Graaf (0.1 fte)

Prof.dr. K.P. Jungmann (0.1fte)
Dr. M.Maucec (0.2 fte)
Prof. dr. R. J. de Meijer (0.5 fte)
Ing. J. Vorenholt (0.1fte)
Prof.dr. R.G.E. Timmermans (0.2 fte)
Dr. H.J. Wörtche (0.3 fte)
N.N. (post-doc vacancy)

Industrial partners:
FOCUS OIL and GAS, BV, Beverwijk.
Hi-Light Opto Electronics B.V., Tolbert.
Lambert Instruments, Leutingewolde.
PerkinElmer, Groningen.
Technologie Centrum Noord Nederland, Groningen.
Schramifa Machinefabriek B.V., Stadskanaal.
Variass Electronics B.V., Veendam.

The South African Team consists of

- iThembaLABS

Dr. F.D. Smit (iThemba LABS), (0.25 fte)

- UCT

Prof. em. dr. F.D. Brooks (0.25fte)
Dr. R.W. Fearick (0.1fte)
Dr. R.Nchodu (0.1fte)