



**Progress Report November 2004-January 2005**

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This document presents an overview of the essential events related to the Earth AntineutRino TomograpHy (EARTH) programme in the period November 2004-January, 2005. This is the third progress report: the previous ones covered the period May-August 2004 and September-October 2004.

### **Funding**

With the start-up 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. In January 2005 we were contacted by the South African Department of Science and Technology to arrange a meeting in February-March 2005 during Rob de Meijer's stay in South Africa.

To obtain funding for the ongoing and upcoming projects in the first phase a variety of funding possibilities have been explored. Since May 2004 we have worked with Technology Centre Northern-Netherlands (TCNN) on the preparation of two applications in the programmes Innovatiesubsidie Samenwerkingsprojecten (IS) of the Dutch Ministry of Economic Affairs. One is focussing on the detector and electronics development, the other is aiming at investigating the feasibility of drilling for an EARTH antenna on Curaçao. In addition financial support for the antenna part is being sought from funds specially dedicated to collaborations with the Netherlands Antilles and in particular Curaçao. These possibilities were discussed with the authorities of the Antilles during the visit that Emiel van der Graaf and Rob de Meijer paid to Curaçao in the first week of January. As promised Prime Minister Ys discussed the EARTH programme with Dutch Minister of Internal Affairs and Kingdom relations De Graaf, in the second week of January. De Graaf indicated that there are in principle two possibilities which have to be investigated. The first contacts have been made.

During the visit to Curaçao, Prime Minister Ys pointed to the possibilities of EU funding. We discussed the matters with the responsible people, who are taking the EARTH programme description to the regional EU office in Guyana to find out what options are available.

Funding usually means that a part of the requested budget has to be supplied via a contribution by the applicants. In the discussions with Dutch and Antillean industries we have found partners that are willing to participate in and contribute to the EARTH programme from both side of their knowledge and expertise as well as the financial side.

### **Curaçao**

November and December were used to further prepare for the visit to Curaçao in January 2005. In the preparations we were assisted by a number of people. Special thanks go to Minister Plenipotentiary Comencia, Mr. J. Saleh and Mr. J.G. Dekker. It resulted in a busy week (See EARTH REP-003) in which Emiel van der Graaf and I met Ministers and civil servants of both the Antillean and the Curaçao governments as well as representatives of industry. In view of creating interest among young Antilleans in sciences we met with the rector and staff members of the University of the Netherlands Antilles (UNA) as well as directors and teachers of a number of high schools. In addition we visited the location of a possible site for the antenna. Emiel and drs. Leon Pors of Carmabi spent two days to take



surface measurements of the intensity of the natural radiation and collected samples for radiometric analysis at the KVI in Groningen.

In the meeting with governments and industry we experienced a genuine interest in the programme. In addition to the scientific questions, the project offers additional interesting aspects to Curaçao in the form of bringing a high technology project to the island with a possibility of establishing a laboratory on the island where young, educated Antilleans can work. The envisaged time span of the project (at least about 25 years) means the creation of durable economics. It will supply about 50 positions for scientists, engineers and technicians and it is expected from experiences with such institutions elsewhere that industrial spin offs will follow. On several occasions we heard that this programme is well aligned with the goal of Curacao to become the Island of Education and Sophistication for the region of the Caribbean and the adjacent parts of South America.



**Figure 1:** *Encounter with Minister Cova at the Kurá Hulanda Hotel. From left to right: Jacob Gelt Dekker, Emiel van der Graaf, Rob de Meijer and Minister Cova. (Courtesy of Antilliaans Dagblad)*

As it takes time to educate people we met with representatives of the UNA and some of the high schools at Curaçao and with the Stichting Studiefinanciering Curaçao. With the latter we discussed possibilities of stimulating high-school students to take up studying in a science direction. With the UNA we discussed their role in educating the science students and possibilities for collaboration with the University of Groningen. In addition the UNA has offered to take a coordinating role in a Hisparc project on Curaçao for high schools. Hisparc is a Dutch project (see [www.hisparc.nl](http://www.hisparc.nl)) in which pupils build a detector for high-energy cosmic rays and measure very-high energy cosmic events in coincidence measurements between signals occurring in detectors placed at some distance apart. We have established a contact between the Dean of the Technical Faculty of the UNA and the Dutch coordinator.

### **Industrial partners**

From a very early stage, 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, the Dutch drilling consulting firm, FOCUS OIL and Gas, and the KVI are preparing a proposal for IS funding of a drilling project. For this project KVI will make a literature survey of information available on the (deeper) geology of Curaçao and select a favourable site to host an antenna. Seismic investigations will be carried out at the site to verify the volume of the geological host formation, as derived from surface information. Subsequently two test drills will be made. The radiometric and geological properties of the drill cores and the boreholes will be investigated. In addition physical parameters such as the temperature profile of this part of the island will be mapped. The latter information is also

interesting for our new Curaçao partner Aquallectra, which produces electricity and water for Curaçao, in view of the possibility of geothermal energy.

Aquallectra, as a partner, will coordinate a number of activities on Curaçao. It will be our contact for the governments and the UNA. Moreover it will take action in requesting permits as well as support the search for various sources of funding.

Following a meeting on 30 September a group of six industries in the northern part of The Netherlands expressed their interest in participating in EARTH. On 28 January 2005 Heinrich Wörtche and Patrick Cnubben (TCNN) met on technological developments and strategic industrial partners with respect to the EARTH detector development. They identified a list of industrial partners to be approached for collaboration, a time line and a list of deliverables. A meeting will be organised with the potential collaborators to formulate a funding application.

### Detector development

In the last progress report the first measurements on a test cell at iThemba LABS, South Africa were described. These measurements simulated the basic principle for antineutrino detection, namely the delayed coincidence method, with the use of a neutron source and a  $^{10}\text{B}$ -loaded scintillator. Moreover the data showed that signals produced by  $\gamma$ -radiation and neutrons can be distinguished by analysing the pulse shapes of the digitized pulses. In the present period the method for detection and storage of the pulse information was improved.

Both in South Africa as in Groningen simulations are made to investigate the feasibility of directional sensitivity for antineutrino detection. The basis for these studies is the kinematics of the reaction in which an antineutrino is absorbed by a proton. In this reaction a positron and a neutron are emitted. In November and December Rob de Meijer spent time at iThemba LABS to combine the two studies. From the studies a number of important conclusions can be drawn. First is the importance of  $^{10}\text{B}$  (boron-10) being present in the detector material. This addition leads to a capture of the neutron by boron, followed by the emission of an  $\alpha$ -particle. The properties of boron lead to an early capture of the neutron, such that it has not lost too much of its original direction.

The  $\alpha$ -particle is stopped instantly and its signal therefore indicates the stopping location of the neutron. Another result of the simulations is that one can estimate the degree of direction sensitivity as function of the diameter of the detector.

Figure 2 shows the probability that the neutron is detected in a long detector with a certain diameter. From the figure two aspects emerge. The directional sensitivity increases with decreasing diameter but also the probability for detection decreases. In other words the

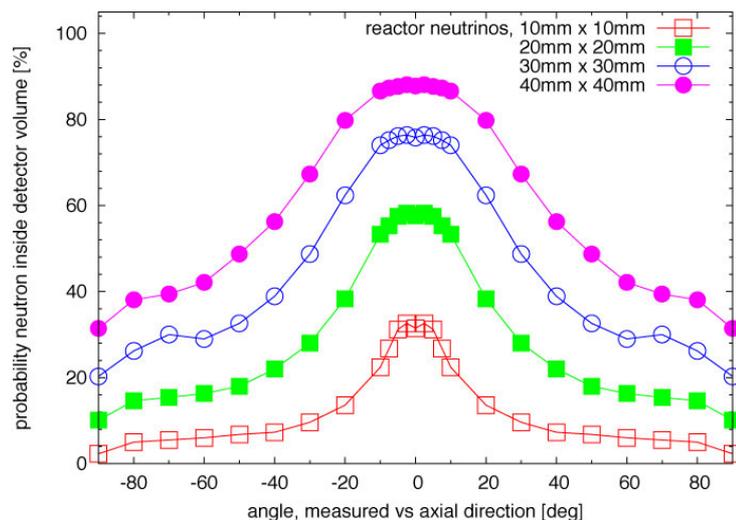


Figure 2: Probability for detecting a neutron, produced in the antineutrino capture on H, in a long detector with a certain cross section. The calculations assume an antineutrino spectrum as produced in a nuclear reactor.

directional sensitivity comes at the expense of the overall sensitivity. This means that directional sensitivity is feasible, but that we have to enhance the acceptance. Some ideas already exist and will be investigated at a later stage. Our present idea is to first test the present results. It is envisaged to build a number of detectors based on this principle and test the directionality in a set-up near a nuclear power plant. In these tests we intend also to further investigate the pulse shapes and to test various ways of improving the signal over background.

In February-March 2005 Heinrich Wörtche and Rob de Meijer will travel to South Africa to discuss and test some of the ideas in preparation for the test measurements, hopefully at the end of 2005.

### **Scientific contacts**

In the beginning of December a small EARTH delegation met with prof. Bernard de Wit, University of Utrecht, NL, to discuss the EARTH programme. This meeting was arranged after FOM director dr. Hans Chang had asked two members of his board (FOM-UB) to advise on FOM's attitude towards EARTH. The first meeting took place with dr. Ben van den Brule, Shell-KSIEPL, Rijswijk at the end of October, see previous progress report. Both members expressed a positive opinion on the EARTH programme.

In the second week of January a KVI team travelled to CERN to present two ideas on future neutrino projects (See EARTH REP-004). The scientific director of CERN, dr. Jos Engelen, suggested that EARTH should apply for "CERN recognised status" after it had become a wider international collaboration. The EARTH programme was one of the ideas presented to a group of neutrino specialist, who were initially sceptical about the idea of directional sensitivity. After the presentation they were surprised to see the feasibility, although they had some reservations on the realisation of a detector made up of so many individual units. The concept for EARTH is a radical change from the monolithic detectors neutrino physicists are used to. Nevertheless, it was expressed that we are welcome to borrow electronics for the test measurements near a nuclear reactor.

On 20 January Prof. G. Fiorentini, Ferrara Italy, gave a general physics colloquium at Groningen on geo-antineutrinos. His visit was used for extensive discussion of the EARTH programme. Also Fiorentini was also sceptical about the directional sensitivity but got rapidly convinced. He will help us establishing contact with the group of neutrino physicists in Gran Sasso.

In the sixth framework of the EU a call for outline proposals in the section Adventure can be submitted before 13 April. Adventure calls for "visionary" proposals with a high impact and a high degree of risk. Since in our opinion EARTH fulfils those criteria we will try to submit an outline proposal. For such a programme we have started seeking possible EU partners with specialisation in geophysics. First contacts have been made with the RWTH-University in Aachen, Germany and the Geological Survey of Finland.

Through the contacts with RWTH-University in Aachen the German Geological Research Centre, GFZ, in Potsdam, approached us on 31 January. GFZ is involved in the International Continental Scientific Drilling Programme (ICDP). Subsequently we approached ICDP with the request for EARTH to be considered by their Scientific Panel for support by ICDP technical groups. Initially this support could be travel and meeting money to consult with their



technicians, engineers and scientists. At a later stage it could lead to funding part of the drilling and assistance in the geophysical measurements in the borehole.

### **Industrial applications**

After initial discussions with NRG-Petten, NL Emiel van der Graaf wrote an initial proposal for the possible application of compact antineutrino detectors for monitoring nuclear power plants. As part of a meeting in the larger framework of the collaboration of NRG and KVI these ideas were discussed with NRG on 17 November 2004. The initial proposal was sent by NRG for consultation to some experts on nuclear reactor technology. The first comments and questions on the proposal will be addressed in the coming month.

### **Seminars and presentations.**

Studiemiddag StralingsBeschermingsEenheid University of Groningen, “*Earth Antineutrino Tomography (EARTH): Op zoek naar de warmtebronnen van de Aarde*”, E.R. van der Graaf, 16 November 2004.

NRG-KVI meeting, “*Radiometric services and nuclear reactor monitoring*”, Emiel van der Graaf 17 November 2004.

Coloquium iThemba LABS, Faure, South Africa: “*Living on a giant stove*”, R.J. de Meijer, 14 December 2004.

ASTRON Dwingeloo, NL: “*Antineutrinos from here to eternity*”, R.J. de Meijer, 16 December 2004.

ASTRON Dwingeloo, NL: “*Technological development for the EARTH (Detector) Project*”, H.J. Wörtche, 16 December 2004.

Werkbespreking KVI, Groningen: “*Feasibility of directional sensitive low-energy antineutrino detection*”, R.J. de Meijer, 20 December 2004.

Curaçao, several presentations, “*Earth Antineutrino Tomography*”, R.J. de Meijer, 2-8 January 2005.

Seminar CERN, Geneve, Switzerland, “*Geoneutrinos*”, R.J. de Meijer, 14 January 2005.

### **Publications and publicity.**

- Popular scientific journals and newspapers

KIJK Magazine, “*Is de aarde een kernreactor*”, December 2004, p 18 (in Dutch).

Amigoe, “*Belangrijke rol Curaçao in groot kernonderzoek*”, 6 January 2005, (in Dutch).

Antilliaans Dagblad, “*Boren naar de kern*”, 10 January 2005 (in Dutch).

The Caribbean Times: J.G. Dekker: “*Turnaround*”, 10 January, 2005.

- Travel reports

EARTH REP-003: *Report on an exploratory visit to Curaçao, 2-9 January 2005.*

EARTH REP-004: *Visit of KVI delegation to CERN, Geneva, 14<sup>th</sup> January 2005.*

- Radio interviews:

30 November, 2004 Paul Harvey, worldwide broadcast via affiliated radio stations.

4 January, 2005: Curaçao radio (TROS Paradise)

- TV interviews

5 January, 2005: Curaçao, Dialoog 2000 (talk show).



### Website and ppt-mastersheets.

A beginning is made to have a web site. Initially it will be part of the KVI website: [www.kvi.nl/~earth/main/htm](http://www.kvi.nl/~earth/main/htm). The website contains a number of reports and a programme description.

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

### EARTH Team.

#### KVI

dr. J.C.S. Bacelar (0.1fte)  
dr. A.M. van den Berg (0.1fte)  
dr. E.R. van der Graaf (0.25fte)  
prof.dr. K.P. Jungmann (0.1fte)  
prof.dr. R.J. de Meijer (0.6fte)  
prof.dr. R.G.E. Timmermans (0.1fte)  
ing. J. Vorenholt (0.1fte)  
dr. H.J. Wörtche (0.3fte)  
N.N. (postdoc vacancy)

#### South Africa

prof.dr. F.D. Brooks (0.25fte)  
dr. R.W. Fearick (0.1fte)  
dr. R. Nchodu (0.1fte)  
dr. F.D. Smit (0.25fte)

#### Advisory Board

prof.dr. H.R. Butcher (ASTRON)  
J.G. Dekker (Curaçao)  
dr. S.K. Kuipers (CvB RuG)  
prof.dr. W.J. Ockels (TUD & RuG)  
prof.dr. H.N.A. Priem (UvA)

#### Industrial Partners

##### *The Netherlands*

Focus Oil and Gas, Beverwijk.  
Hi-Light Opto Electronics, Tolbert.  
Lambert Instruments, Leutingewolde.  
PerkinElmer, Groningen.  
Schramiva, Stadskanaal.  
Technologie Centrum Noord Nederland (TCNN), Groningen.  
Variass Electronics B.V. Veendam.

##### *Curaçao*

Aqualectra.