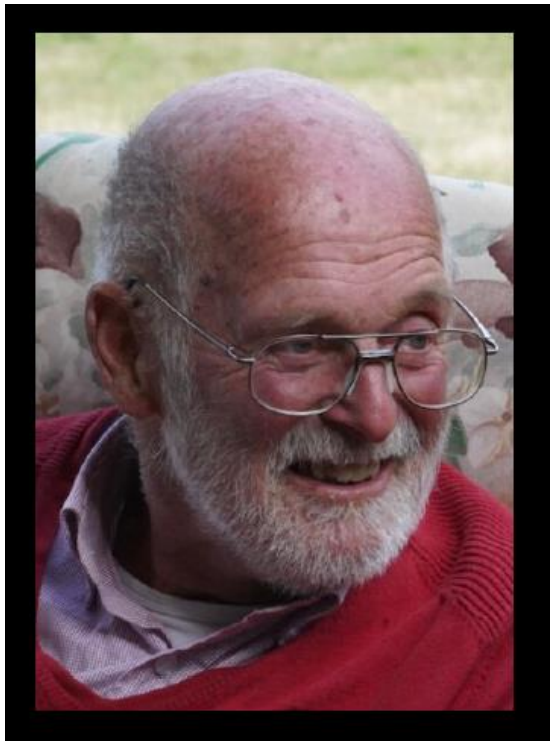
EARTH, a meeting of neutrino- and nuclear-physics



Dedicated to RJ de Meijer
21/7/1940 - 1/11/2019

RJ de Meijer† and FD Smit

EARTH

NRF National Research Foundation 20 1999-2019

iThemba LABS Laboratory for Accelerator Based Sciences

RESPICE PROSPICE

UNIVERSITY of the WESTERN CAPE

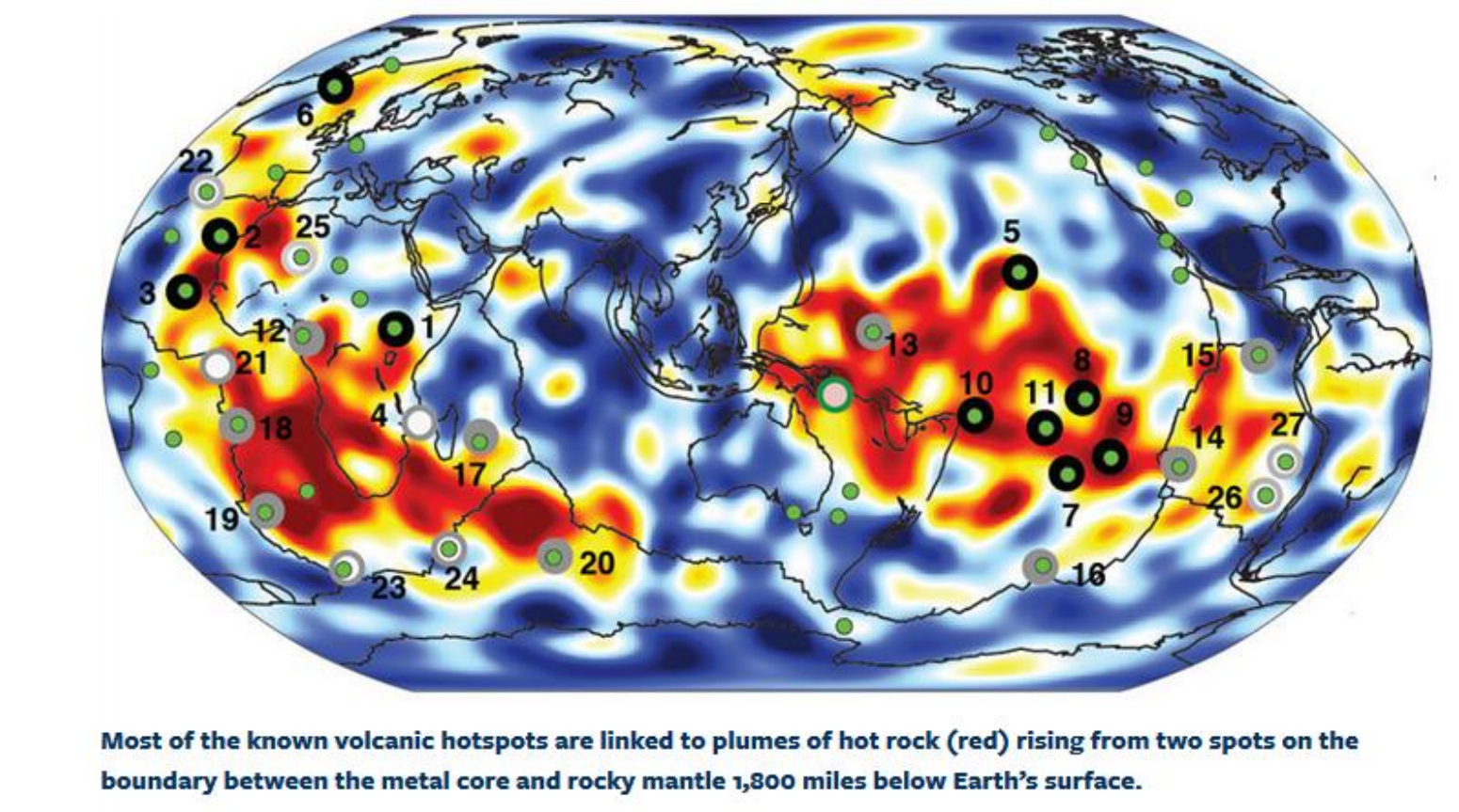
Grateful thanks to all collaborators

Rob de Meijer†, EARTH and UWC
Frank Brooks†, UCT

Roger Fearick, UCT
Milton van Rooy, US (PhD) now NMISA
Jaco Blankenberg, US (MSc)
Mathew Segal, UCT (MSc)
Paul Papka, US
Robbie Lindsay, UWC
Heinrich Wörtche, INCAS^3 now TU Eindhoven
Richard Newman, iTL now US
Rudolph Nchodu, UCT now iTL
Andy Buffler, UCT
SW Steyn, ESKOM

† Deceased

Is the source of the heat radioactive?



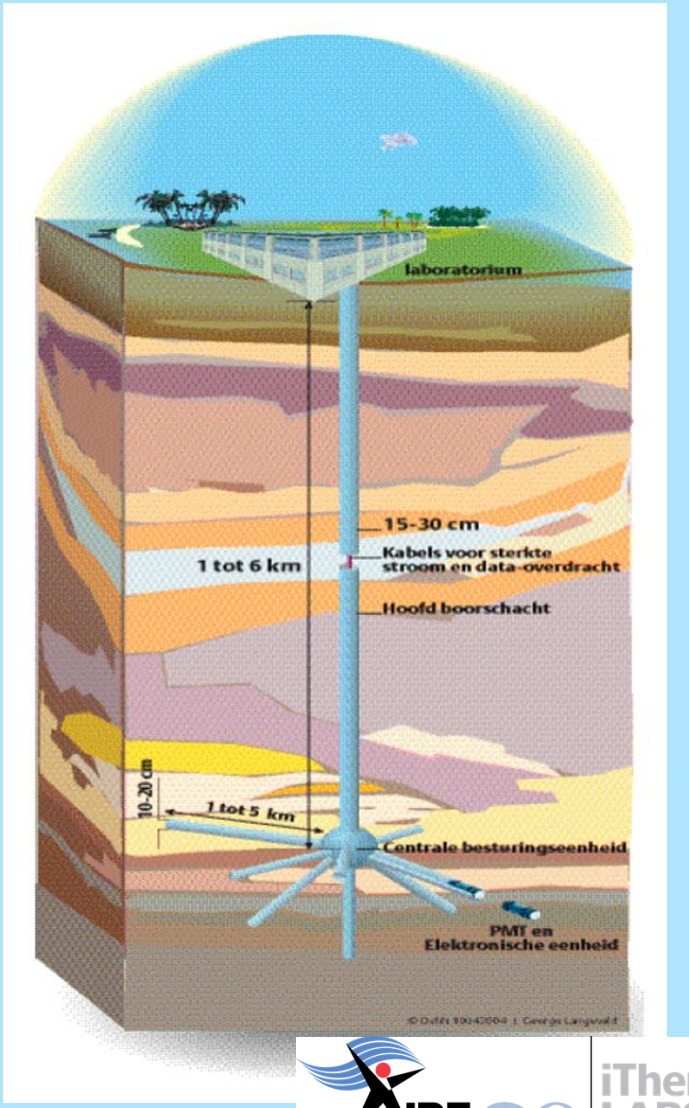
Most of the known volcanic hotspots are linked to plumes of hot rock (red) rising from two spots on the boundary between the metal core and rocky mantle 1,800 miles below Earth's surface.

https://news.berkeley.edu/2015/09/02/ct-scan-of-earth-links-deep-mantle-plumes-with-volcanic-hotspots/

Earth AntineutRino TomograpHy (EARTH)

Formed 2005

AIM : 3D image of radiogenic heat sources inside the earth

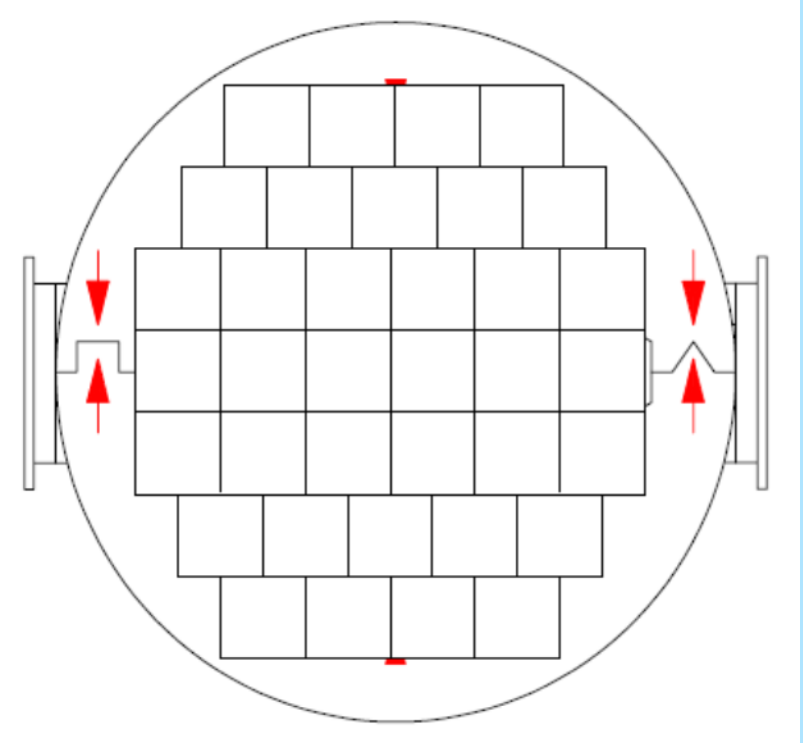


Dagblad van het Noorden, Netherlands.10/4/04

Direction Sensitivity Requirement Informs Design

$\bar{\nu} + p \rightarrow e^+ + n$

Highly modular detector consists of very, very many long thin bars



Face on view

Why?

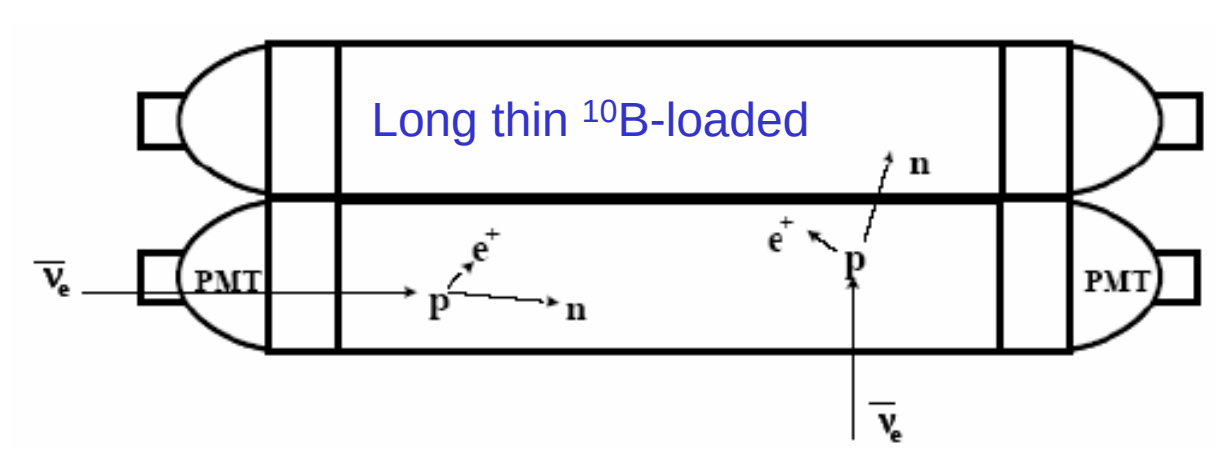
a) Simulations

Roger Fearick and

Jaco Blanckenberg (MSc)

New point of departure :

Determine the **direction** of the geoneutrino



e^+ : carries most of the energy

n : carries most of the momentum

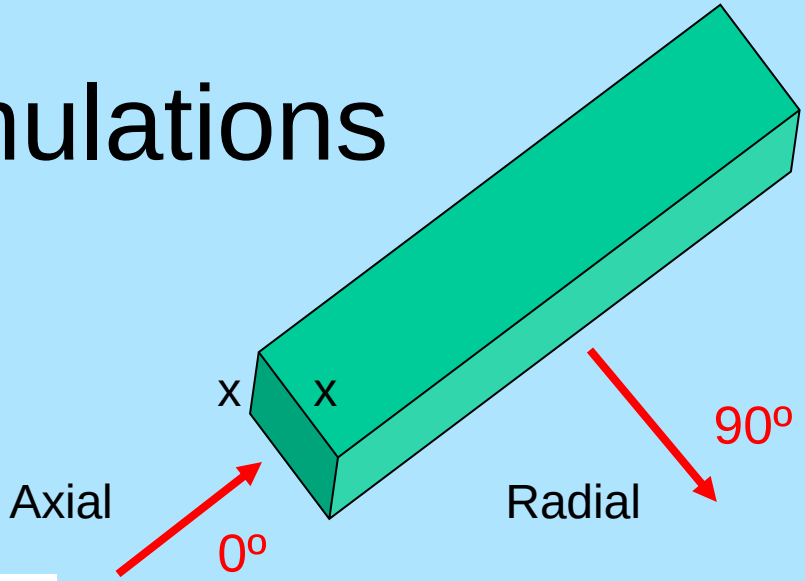
Direction determination depends on how quickly one can stop the neutron

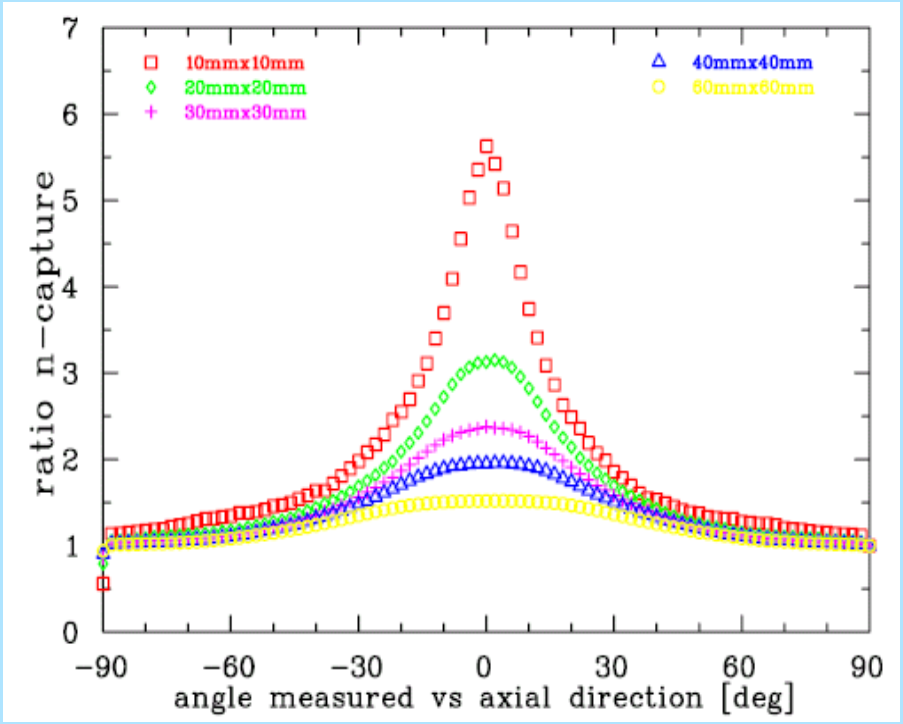
^{10}B-loaded scintillator

Detect charged particles!

Monte Carlo Simulations

4 MeV antineutrinos

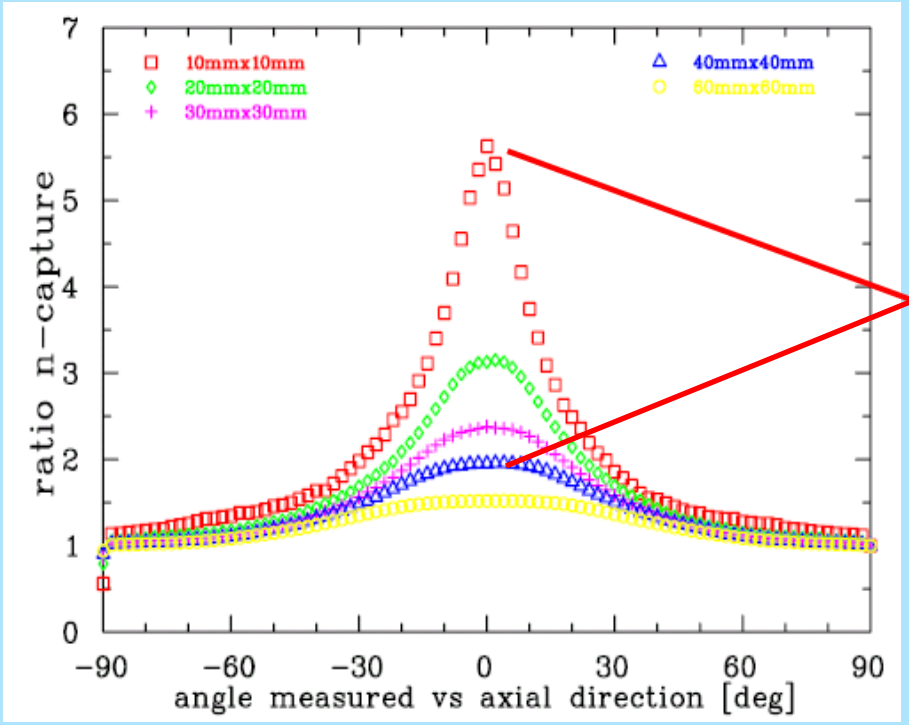


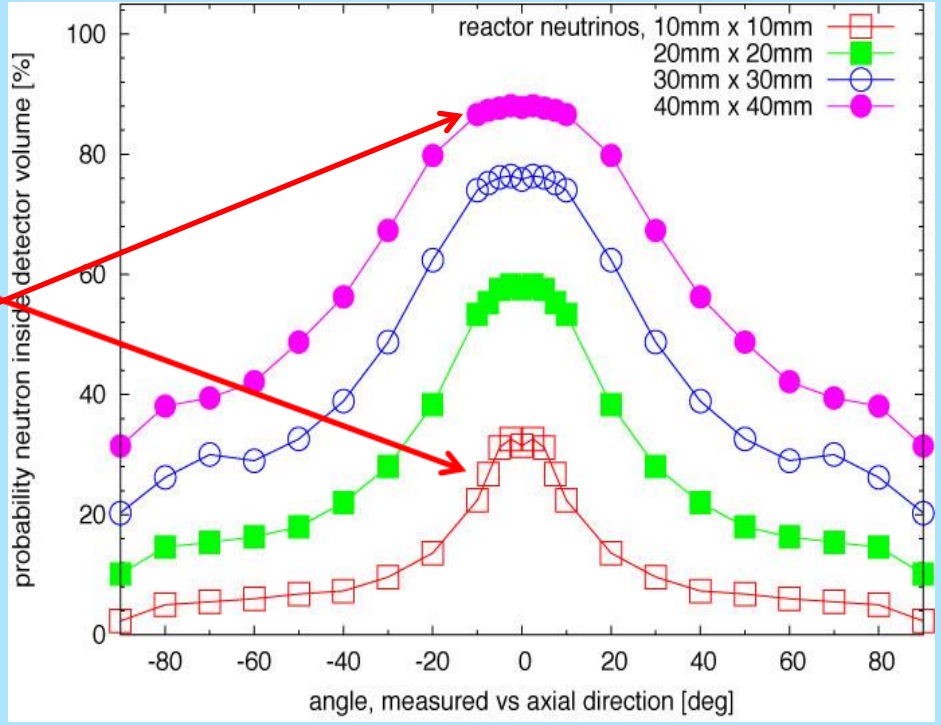


$$\text{Ratio} = N_{axial} / N_{angle}$$

Compromise needed

directional efficiency
vs
scintillator width





Towards Earth AntineutRino TomograpHy (EARTH), RJ de Meijer, FD Smit, FD Brooks, RW Fearick, HJ Wörtche F Mantovani, Earth, Moon, and Planets (2006) 99:193 (AAP Hawaii 2005)

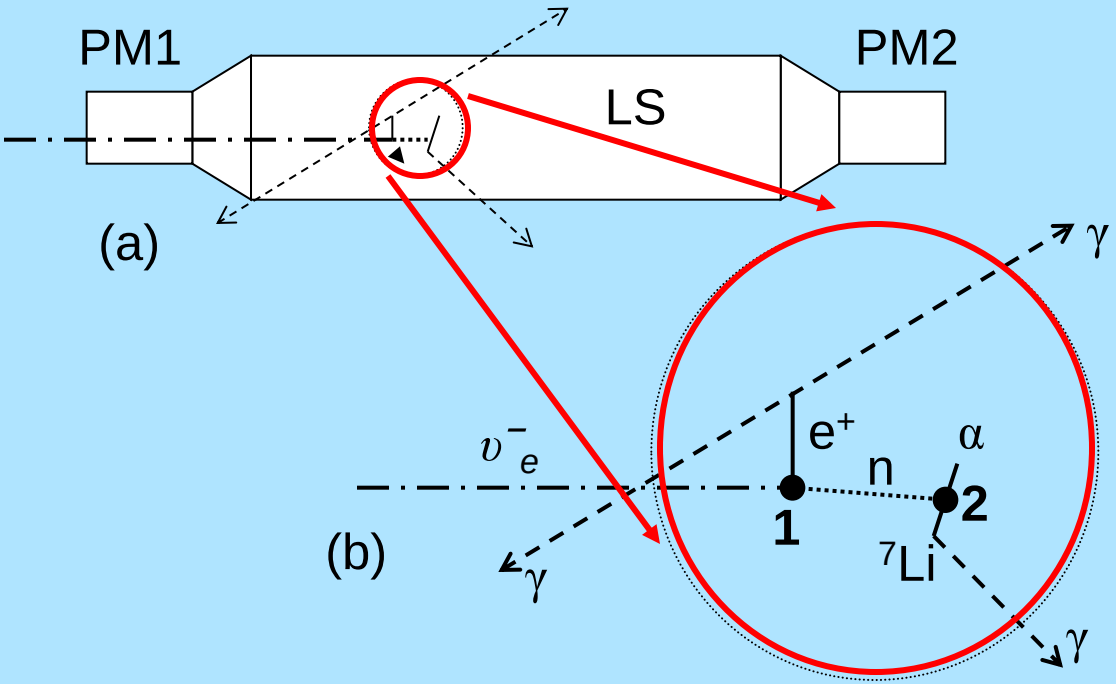
b) Detector Tests

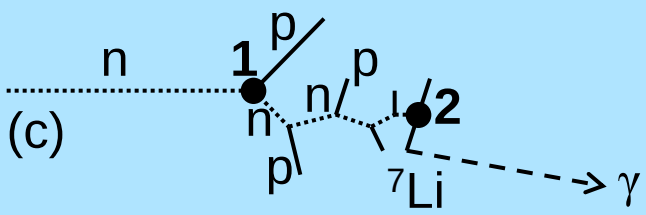
Double pulse Simulations

Frank Brooks, myself and

Matthews Segal (MSc)

Antineutrino detector (iTL / UCT)





(a) schematic overview

LS = liquid scintillator (^{10}B-doped)

(b) antineutrino event

1. $\bar{\upsilon}_e + p \rightarrow e^+ + n$
2. $^{10}B + n \rightarrow {}^{7}Li^* + \alpha$

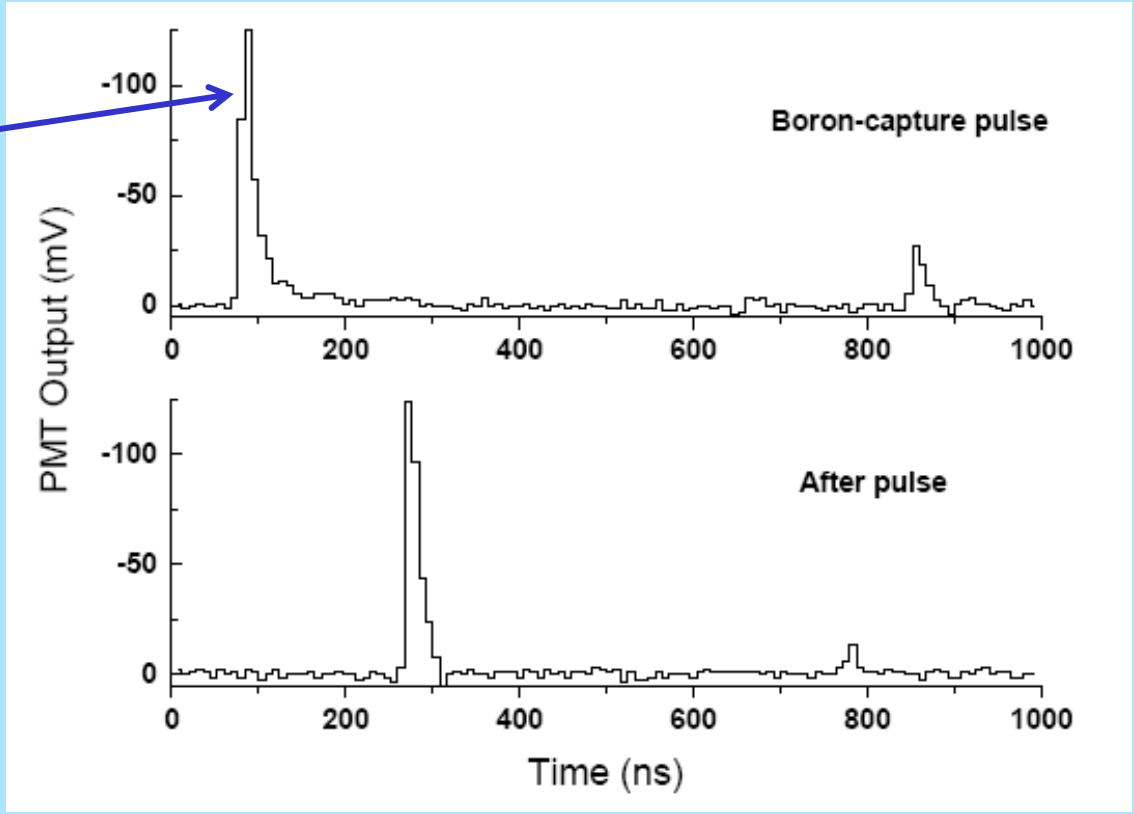
(c) neutron "simulated" event

1. n-p scattering
2. $^{10}B + n \rightarrow {}^{7}Li^* + \alpha$

PSD distinguishes between (b) and (c) via the e^+ and p at 1.

Simulated double pulse digitally recorded

Proton recoil



Neutron source

Small pulses require small scintillators !!

Detector must be highly modular!!!

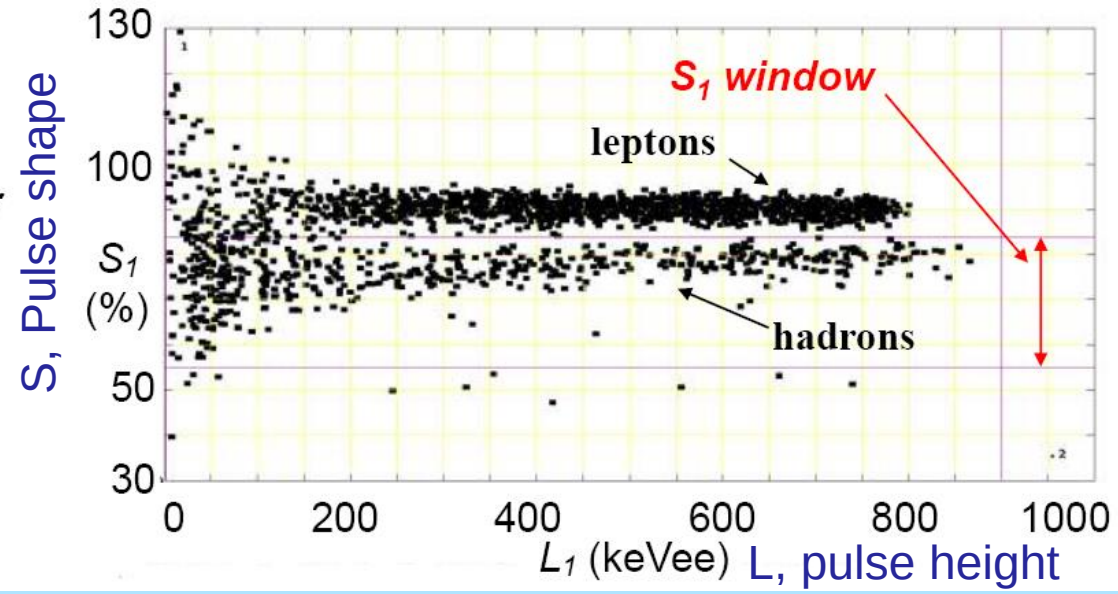
- Neutron detection, the key to direction sensitive geoneutrino detectors, F.D. Smit, R.J. de Meijer, F.D. Brooks, R.W. Fearick, H.J. Wörtche,
- Progress of Science, FNDA (2006) 96 and
- A Direction-Sensitive Detector for Electron Antineutrinos FD Brooks, M Drosg, FD Smit

AIP Conf. Proc. 1412, 177 (2011)

Neutron source digital double pulse data

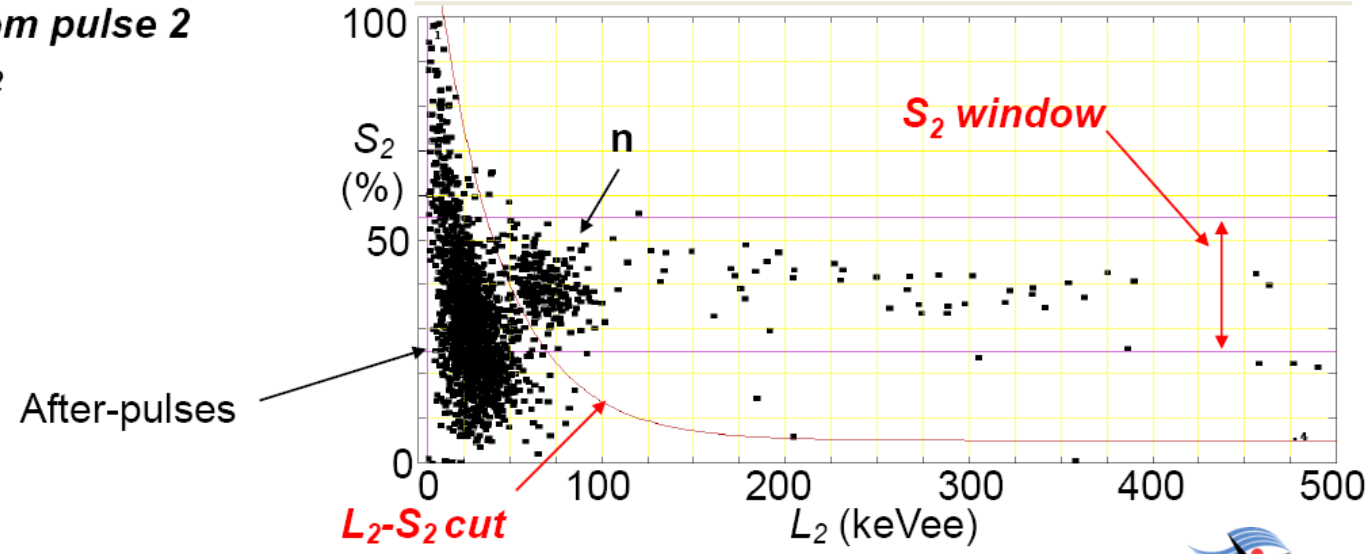
PSD from pulse 1
L_1 vs S_1
2240 events in 2 hr

^{252}Cf source



After analysis

PSD from pulse 2
L_2 vs S_2



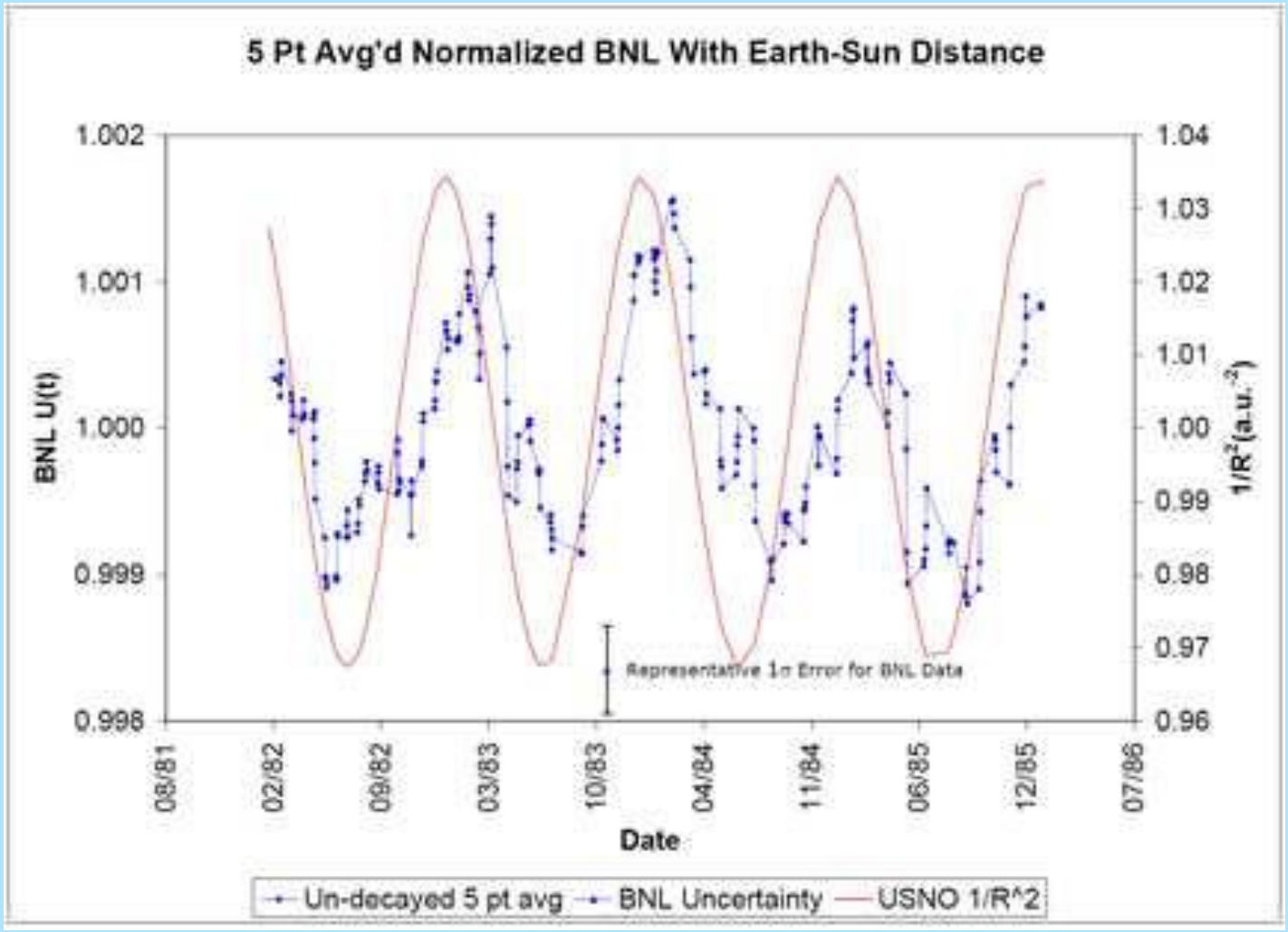
Brooks, Drosg and Smit, 11th Conf. App. Nucl. Tech., Crete 2011

- Future ?
- Problem is highly flammable and toxic liquids
- Now solid scintillators with PSD (EJ299-33)
- Borated?

.....Then something happened

Claim ^{32}Si β^- decay rate affected by distance to Sun

Normalised rate after corrected for decay



J. H. Jenkins, E. Fischbach, Astroparticle Physics 31 (2009) 407, or, arxiv 0808.3283.pdf

0.9×10^{10} $cm^{-2}s^{-1}$ neutrino flux => 0.3% decay change

Our β^+ source tests at research reactor

^{152}Eu, ^{137}Cs, ^{54}Mn and ^{22}Na tested at research reactor in flux of 5×10^{10} $cm^{-2}s^{-1}$

No evidence for antineutrinos significantly influencing exponential β^+ decay
R.J. de Meijer et al., App. Rad. and Iso. 69 (2011) 320 - 326

^{22}Na strange – slight negative effect

Intrestingly!

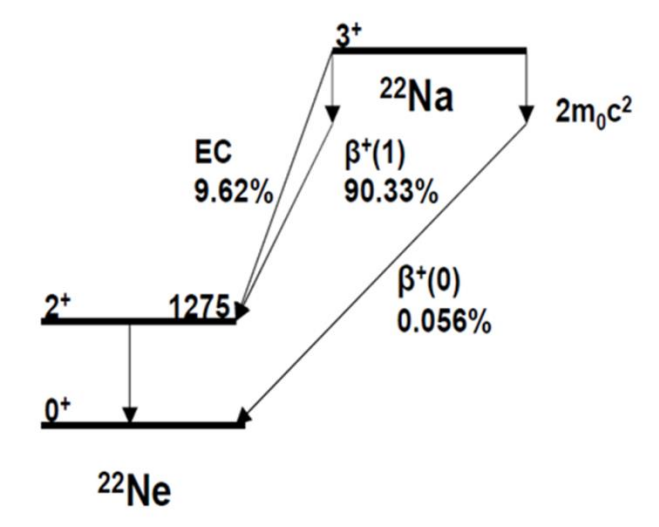
V.E. Barnes et al. App. Rad. and Iso. 149 (2019) 182–199
Similar experiments :-
--- ^{22}Na also strange

Antineutrino capture on a β^+ source

$$^{22}Na \longrightarrow {}^{22}Ne + e^+ + \nu$$

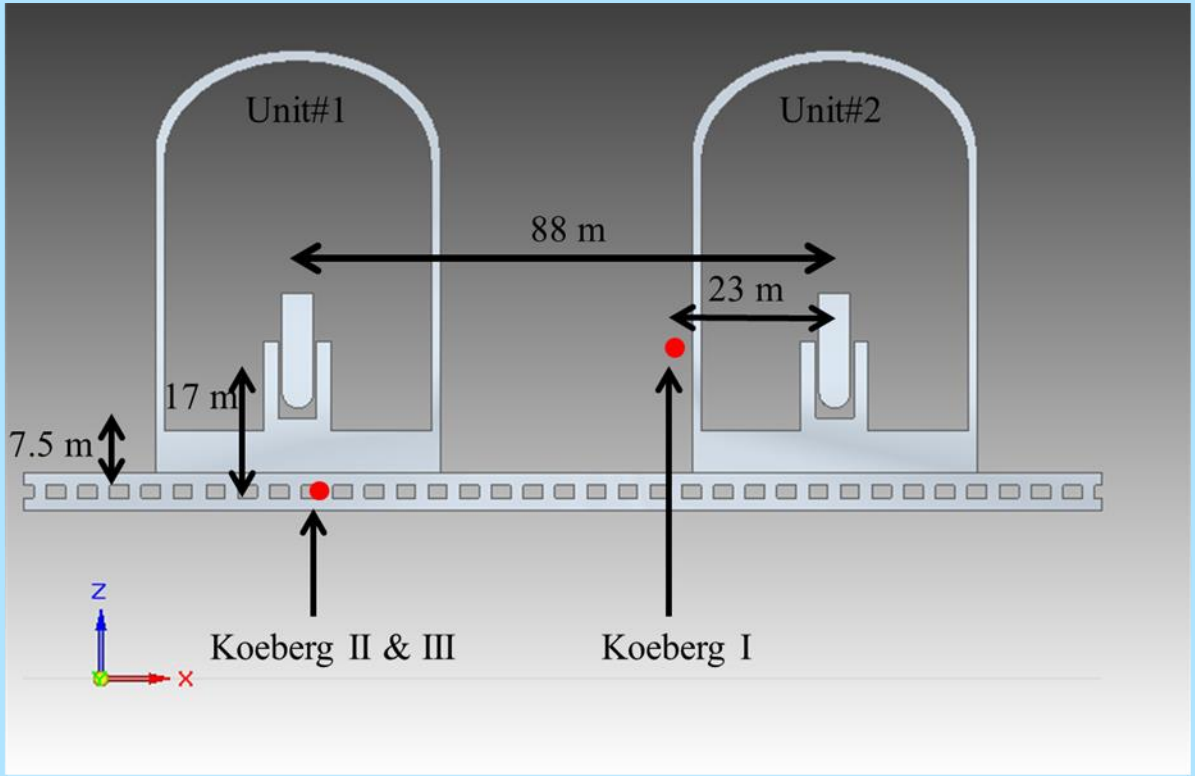
$$\bar{\nu} + {}^{22}Na \longrightarrow {}^{22}Ne + e^+$$

This type of reaction has no threshold



Decay tests at Koeberg Power Station

Milton van Rooy
PhD



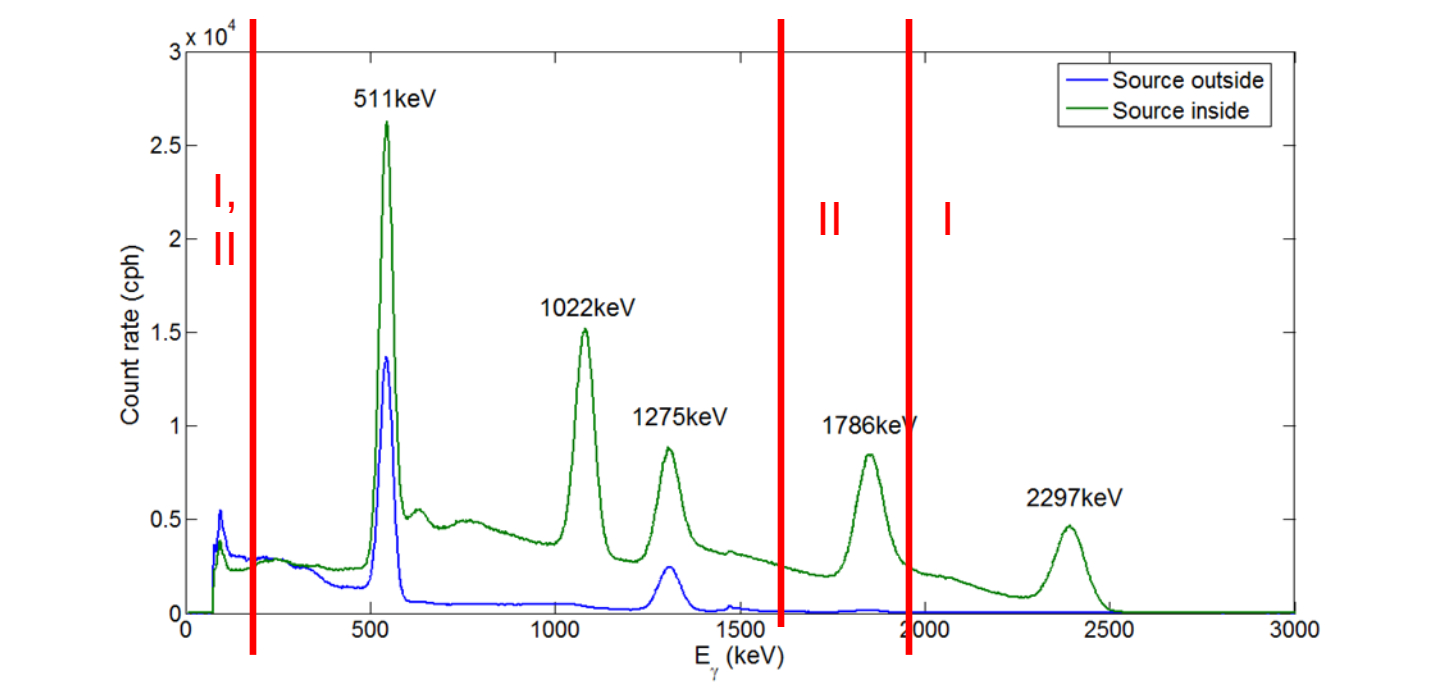
Later - ^{22}Na and NaI well detector

Antineutrinos : ~1.5x10^{13} cm^{-2}s^{-1} at 8 m

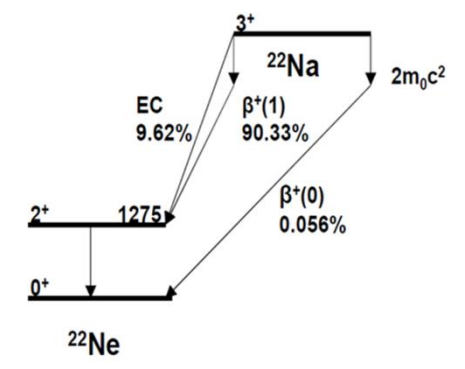
NaI well detector data

I
143 – 1909 keV

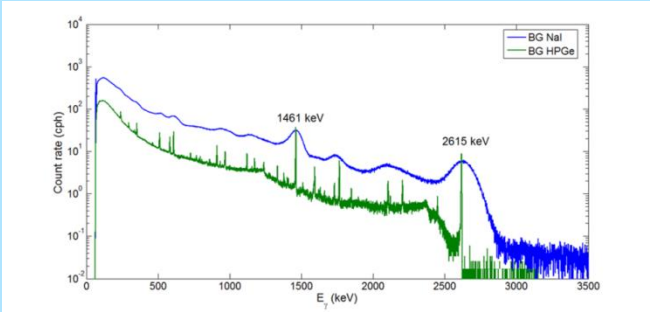
II
143 – 1568 keV



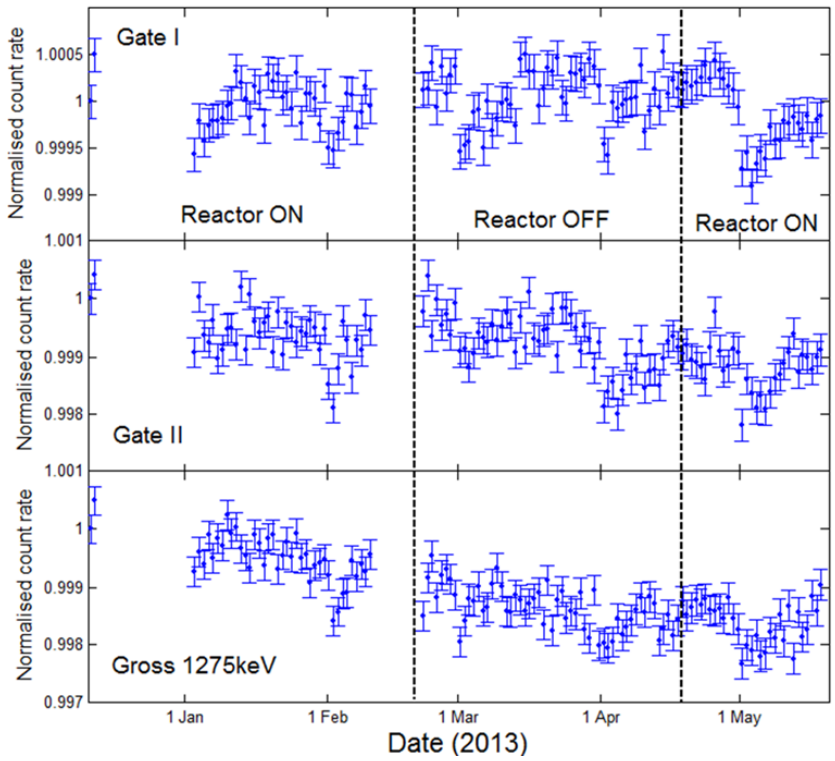
Very little background

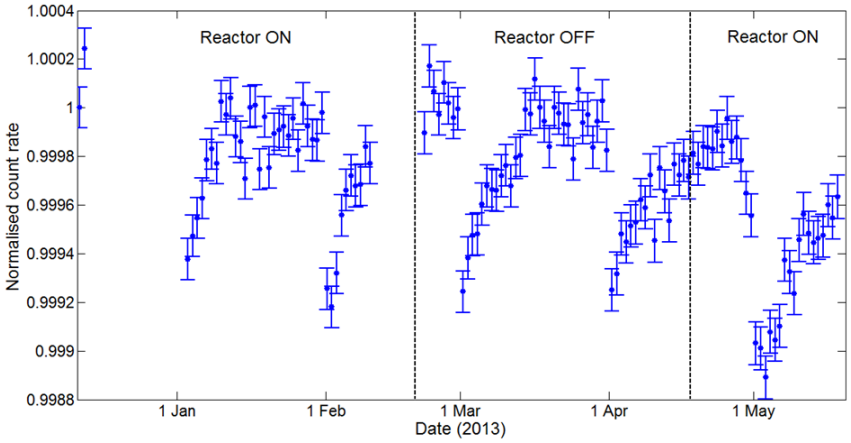


Consistent background subtraction always tricky!



Some Results

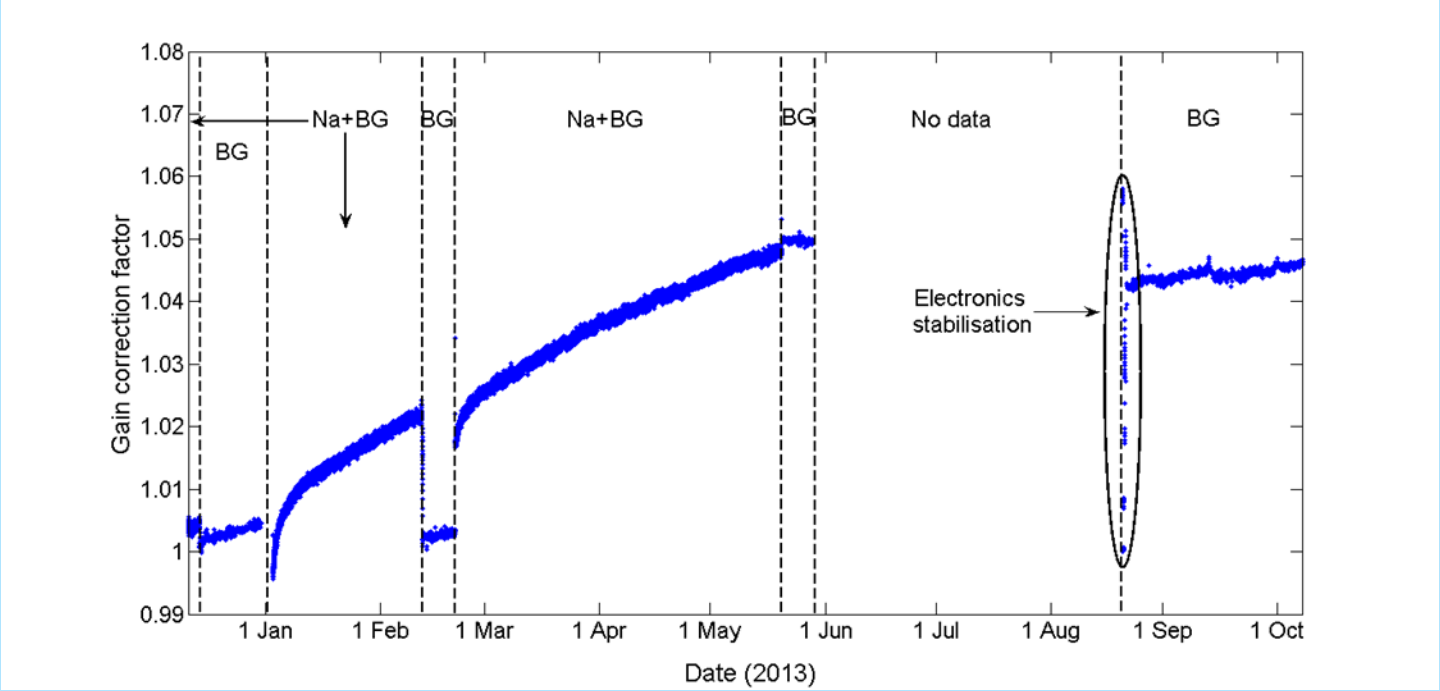




Arguably within uncertainties, no effect

Strange monthly oscillation! Turned out to be monthly pc admin!

Long term measurement difficulty



Gain correction over time !

Future?

- Further data collection at Koeberg.
- Investigate alignment in crystals
- Many people working on spintronics

See www.geoneutrino.nl
for latest EARTH work

1st Law of de Meijer :

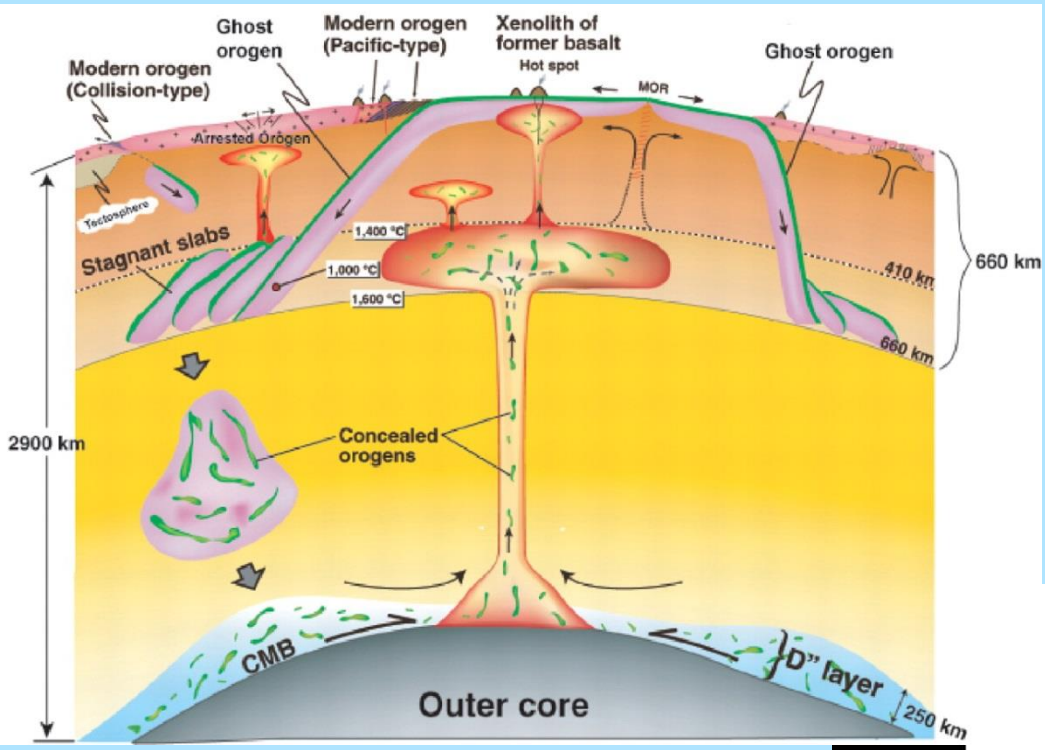
Trouble is conserved!

Thanks you

for

your attention

Superplume under Africa



M. Santosh, et al. Geological Society, London, Special Publications, 338, (2010) 77-116

Good places for geoneutrino detector?
Heat sources under Africa.

Andy Nyblade,
Pennsylvania State University,
Imaging the African Superplume
Using Africa Array Data
Youtube