Taking a picture of the Earth's Interior with Geoneutrinos

Bärnfels

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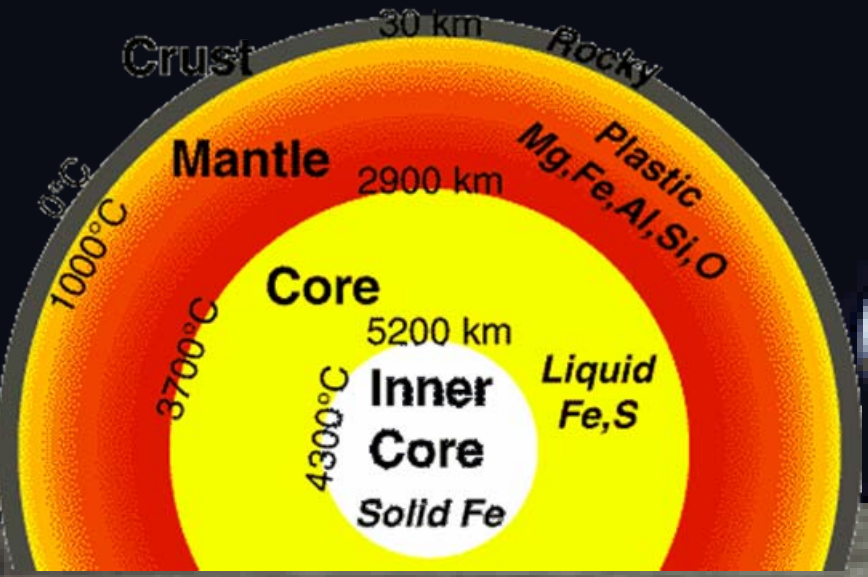
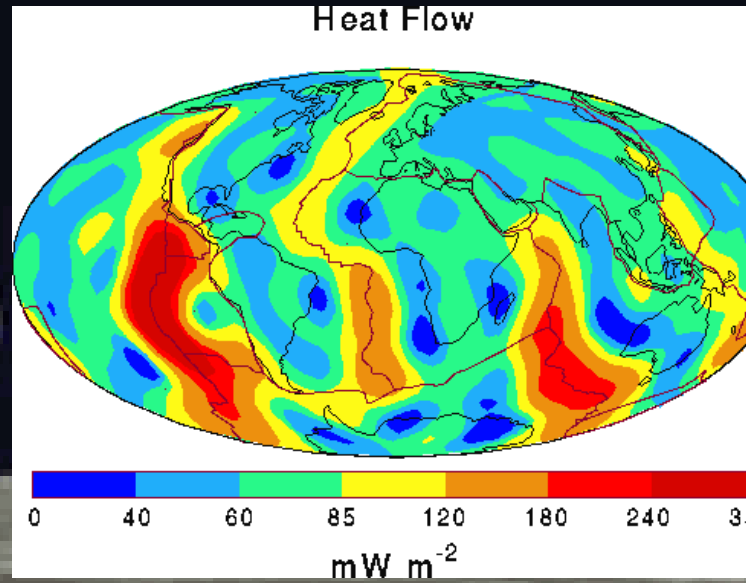
The Earth's Interior





Element	mean life (Gyr)	# of neutrinos	Isotopic abundance	Energy released
^{40}K	1.84	1	0.0117%	~1.4 MeV
^{238}U	6.45	6	99.2745%	51.7 MeV
^{232}Th	20.3	4	100%	42.5 MeV

What do we know about Earth's Interior?

Density obtained by monitoring seismic activities

Bulk Silicate Earth Model for Crust-Mantle based e.g. on planetary and meteoritic probes

But: deepest drill-holes ~ 10km

Deepest mantle material (volcanoes) ~ 100km

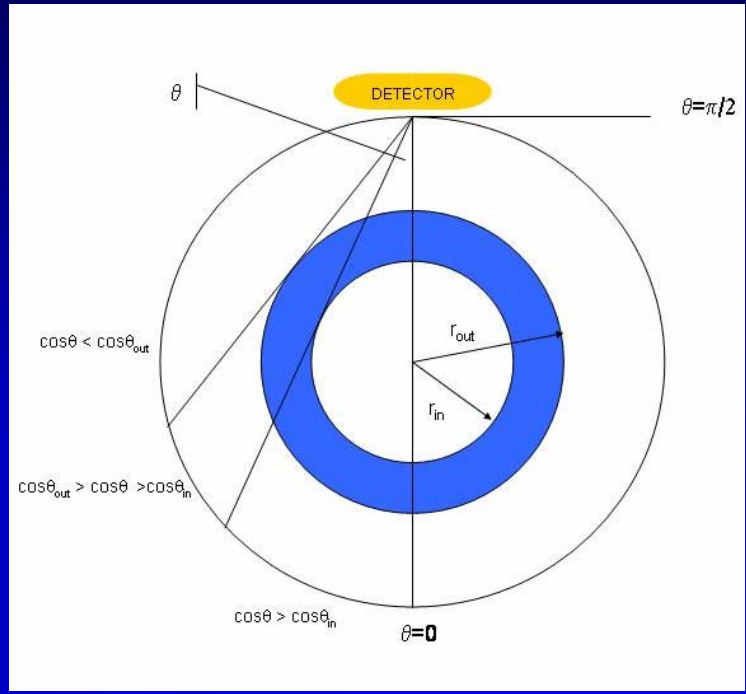
No detailed information about the core!

Only 50% of terrestrial heat flow explained!

⇒ ***Earth's Interior still a mystery***

First steps to get a neutrino picture of the earth

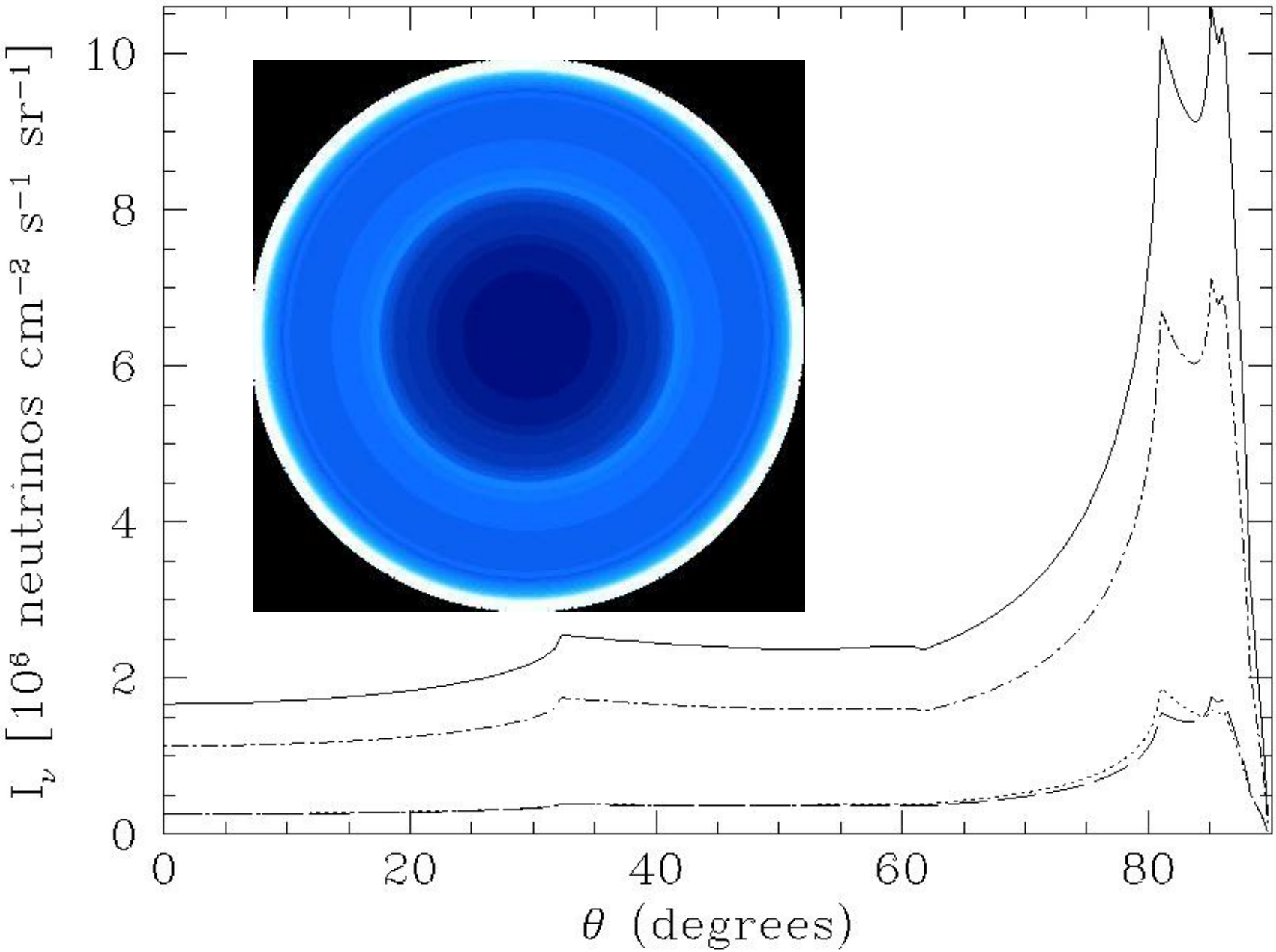
Using the density profile given in the Preliminary Reference Earth Model to Divide Earth into shells of constant density



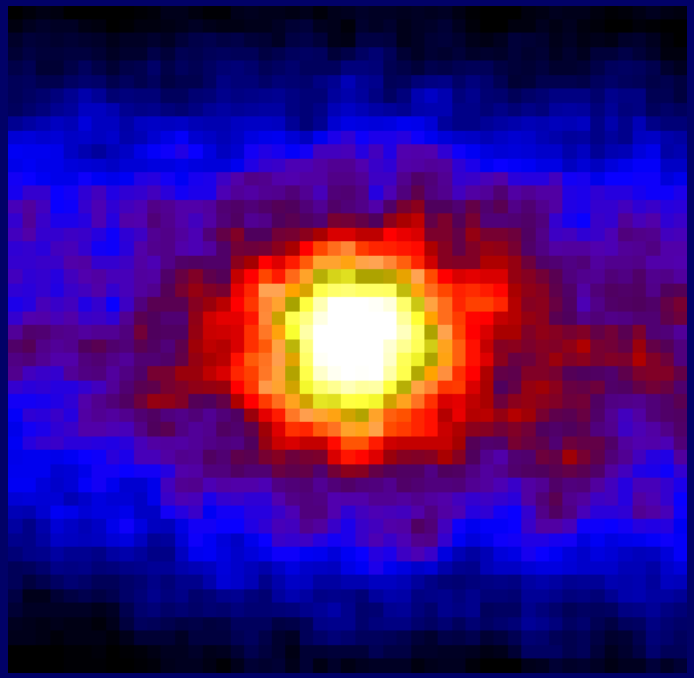
$$I_i(\vartheta) = I_{i,0}\, g(\vartheta)$$

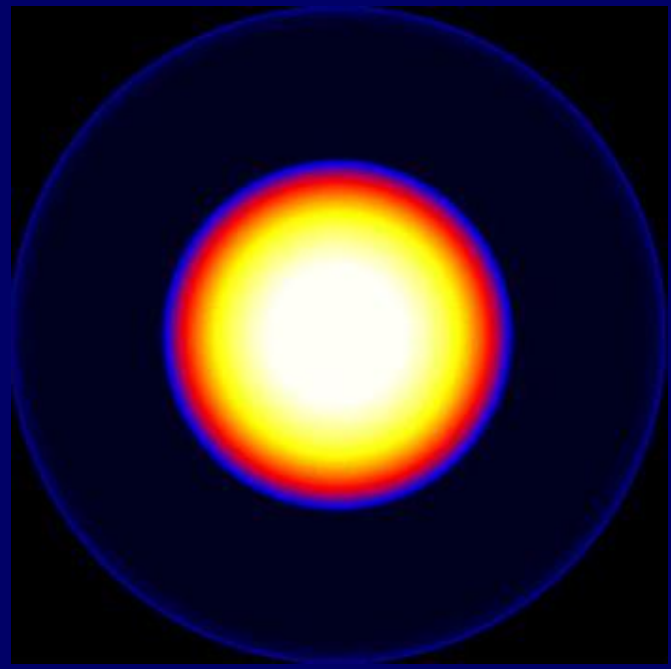
with

$$I_{i,o} = 2\,\frac{N_i a_i \rho R_\oplus}{4\pi A_i m_u \tau_i}$$


L_ν [10^6 neutrinos cm^{-2} s^{-1} sr^{-1}]
0
2
4
6
8
10
0
20
40
60
80
θ (degrees)

Sun vs. Earth

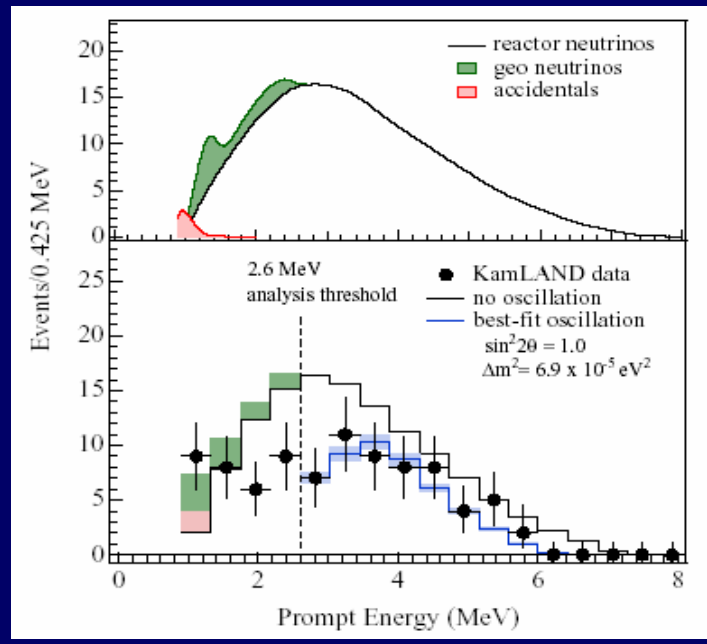


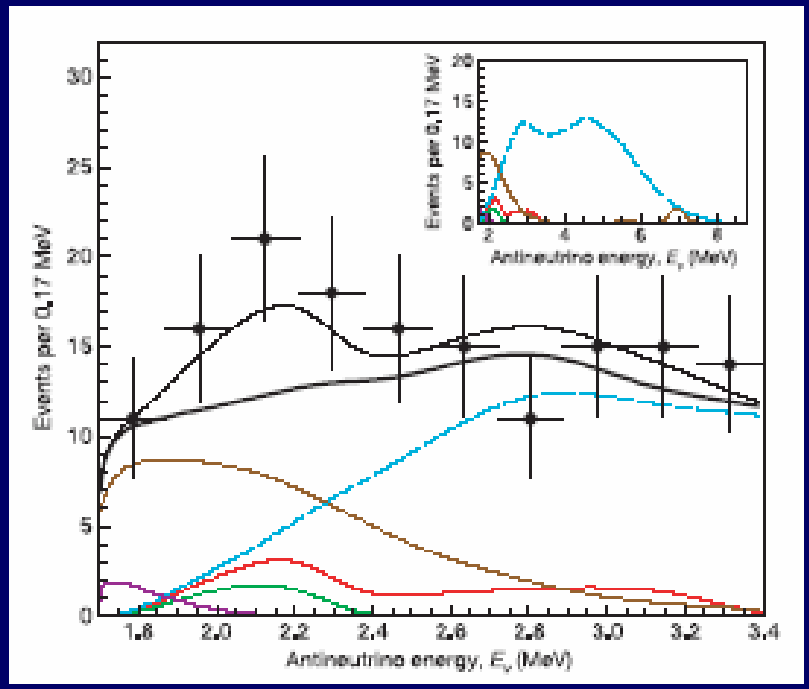


http://elvis.phys.lsu.edu/svoboda/superk.html

Detection via $p + \bar{\nu}_e \longrightarrow n + e^+$

First events from KamLAND (1kton):

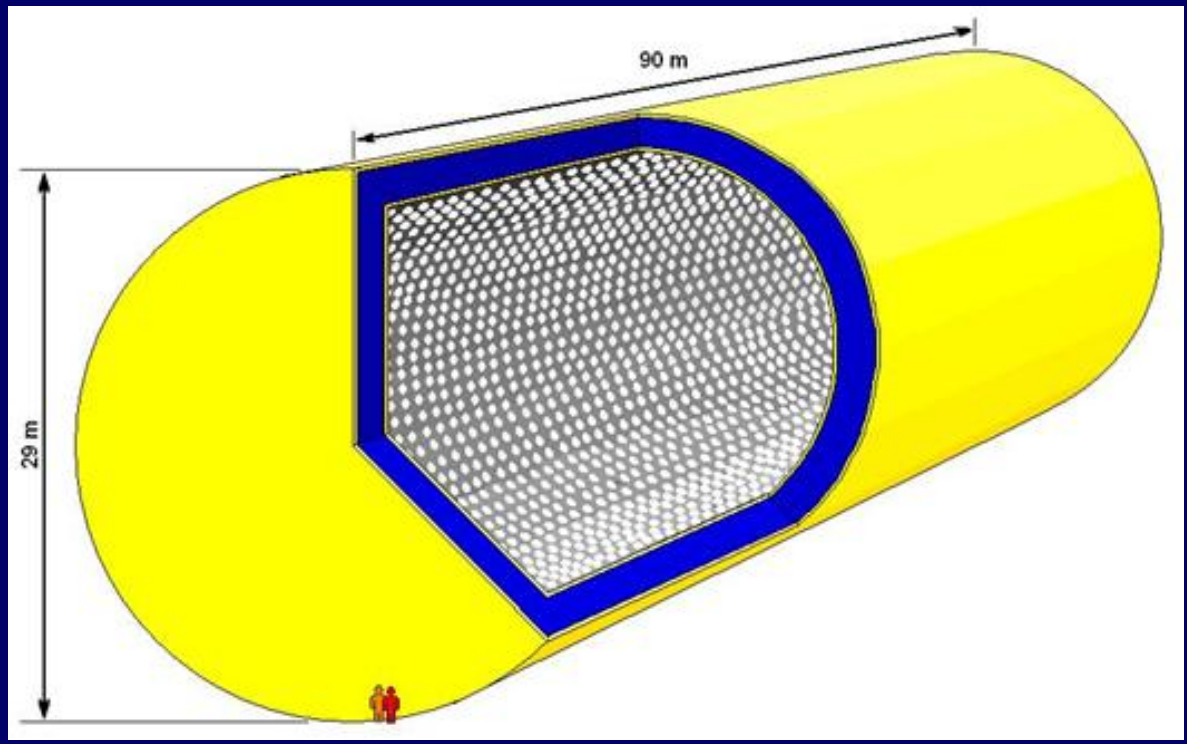




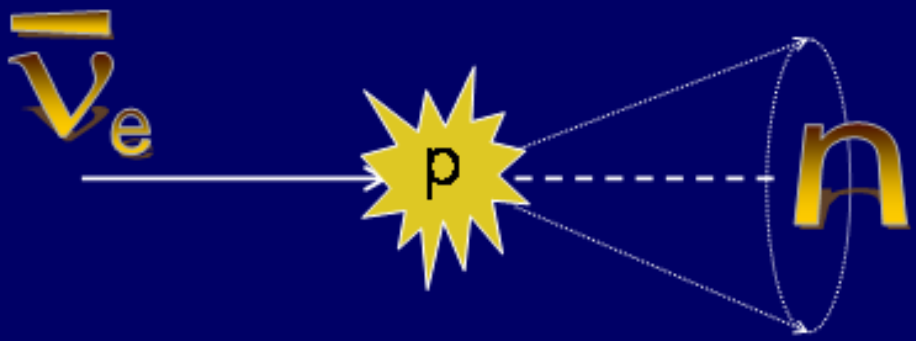
4.5-54.2 geoneutrino events

data 2005

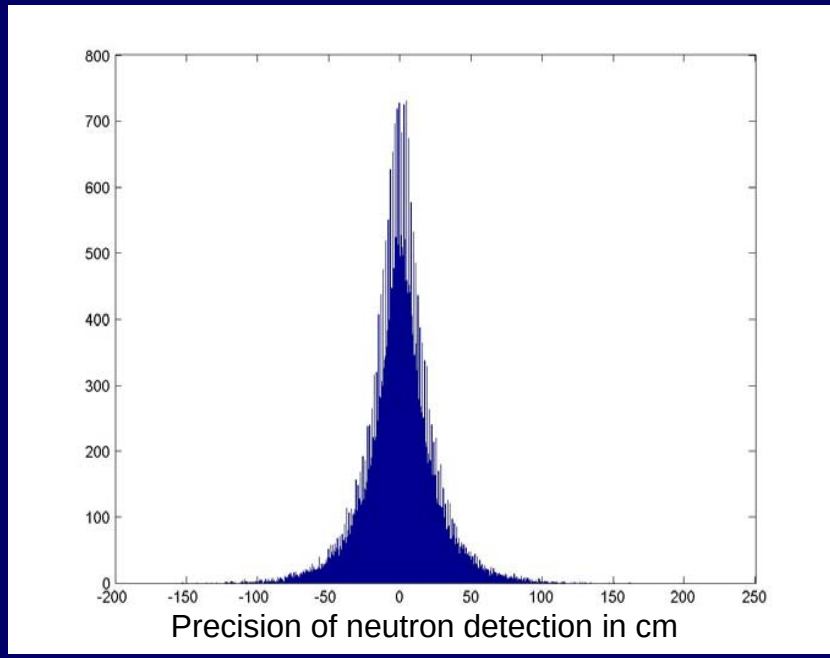
Next generation: 50 kton liquid scintillation detector: LENA



Angular Resolution

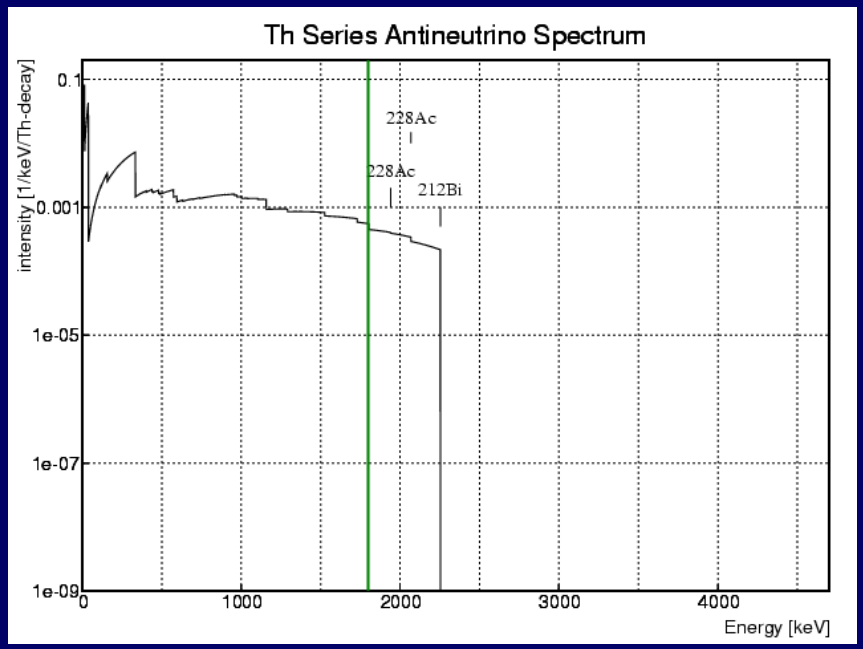


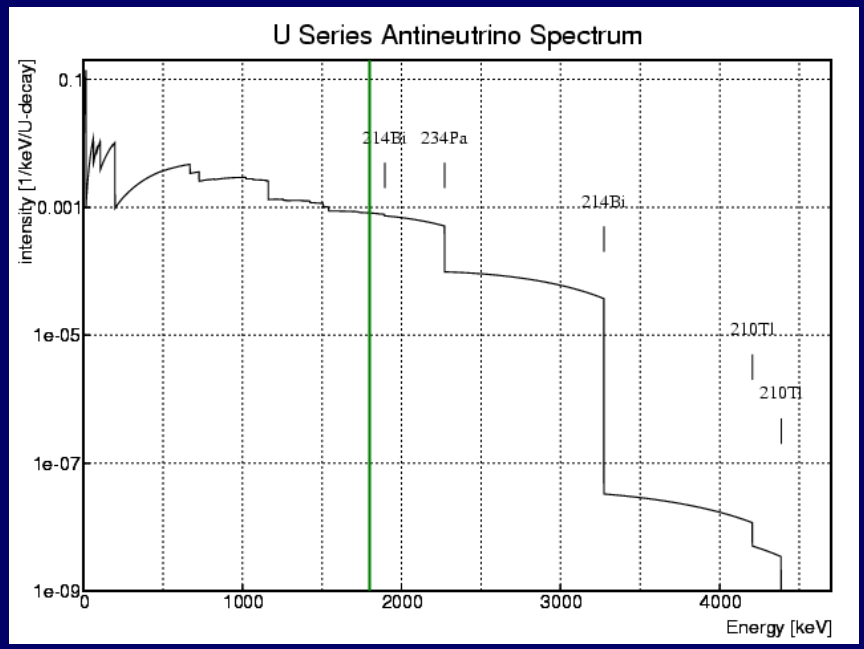
Sensitivity of LENA + resolution of CHOOZ (18°)



➔ Angular resolution of LENA: ~30° (half-cone aperture)

Measurable Spectra





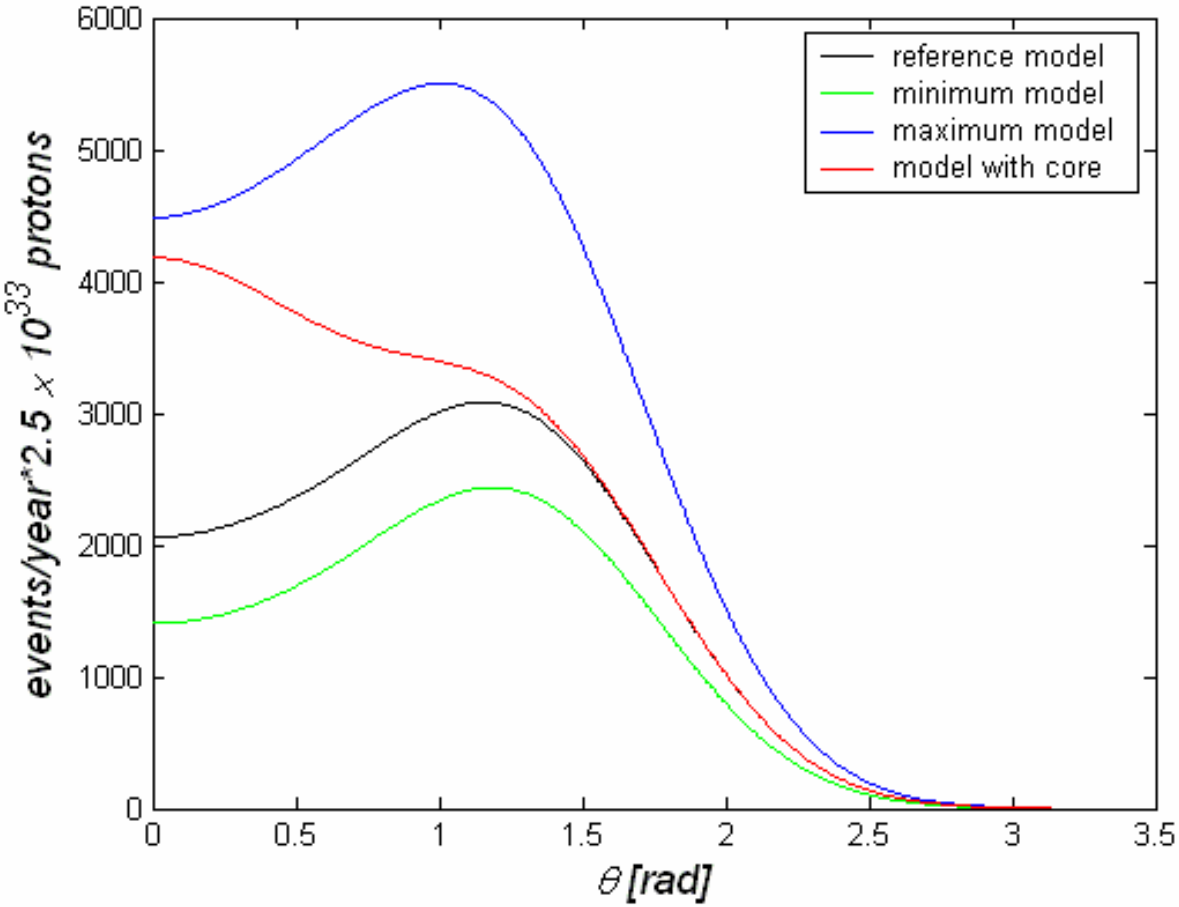
U/Th ratio measurable

Conclusions for K abundance possible

Note: Only 13% of uranium neutrinos and 9% of thorium above 1.8 MeV

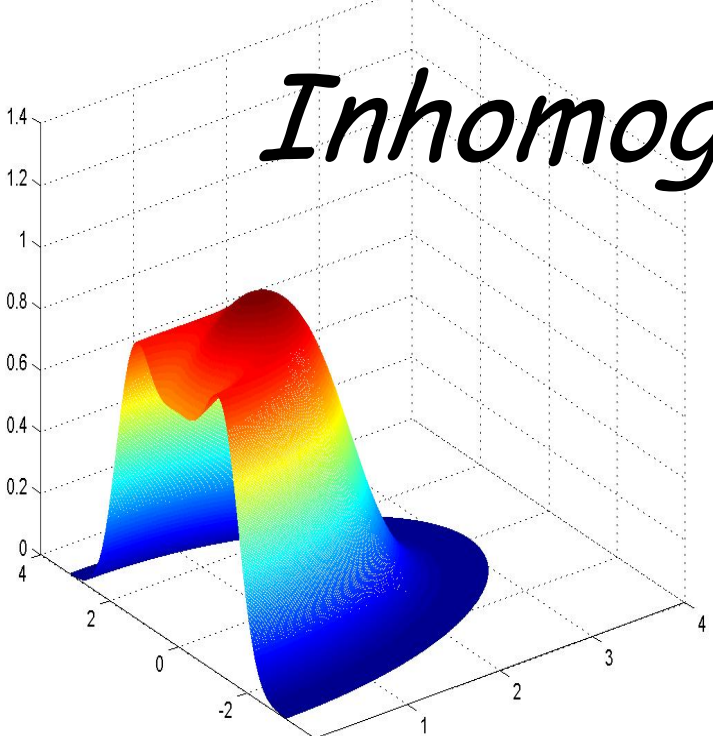
Continental Crust Models

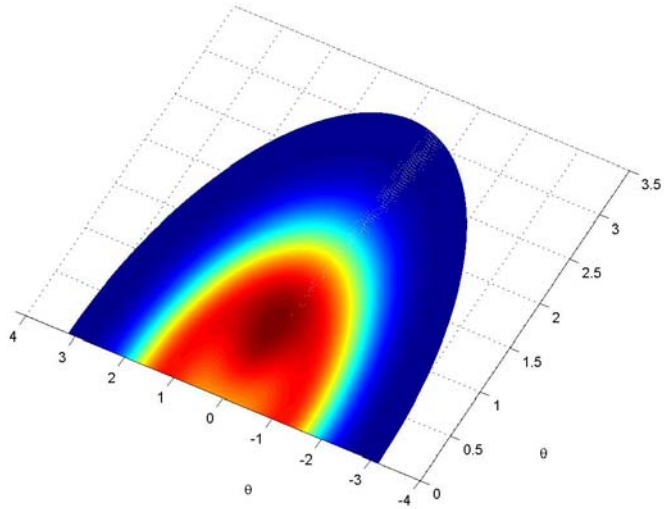
Direct Comparison :

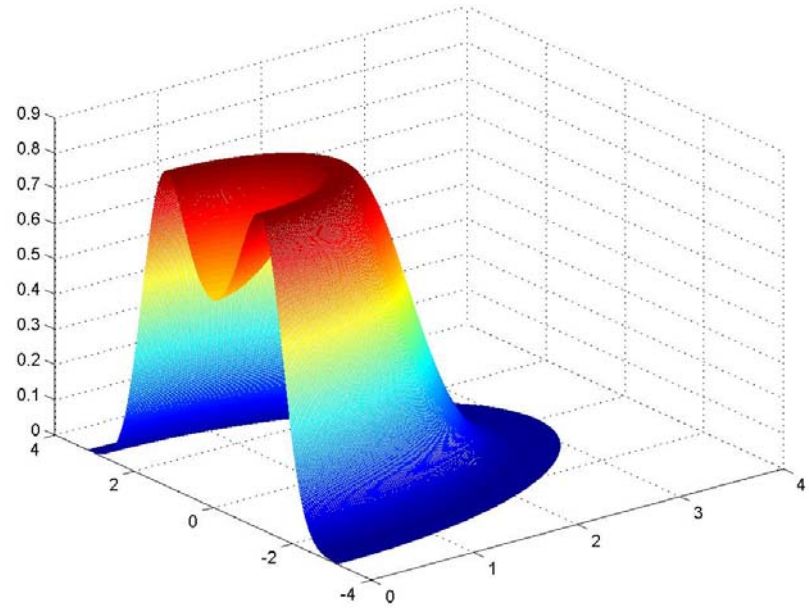


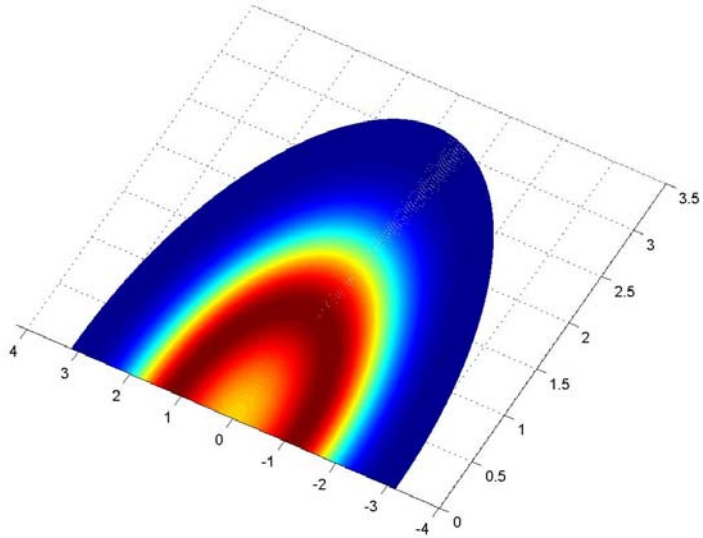
	0° < θ < 30°	30° < θ	total	ratio
ref	1081 ± 33	4020± 63	5102 ± 71	0.27 ± 0.01
min	750 ± 27	3195 ± 56	3945 ± 63	0.33 ± 0.01
max	2321 ± 48	7015± 84	9336 ± 97	0.24 ± 0.01
core	2011 ± 45	4537 ± 67	6548 ± 81	0.44 ± 0.01

Inhomogenous Earth









Summary-what can we do?

- Test the U/Th of Bulk Silicate Earth
- Test how much of the heat is primordial
- Get the distribution of radioactive elements throughout the earth
- Test if there are radioactive elements (only potassium?) in the core
- Test other things (nuclear reactor in core?)
- Search for inhomogeneous sources

References:

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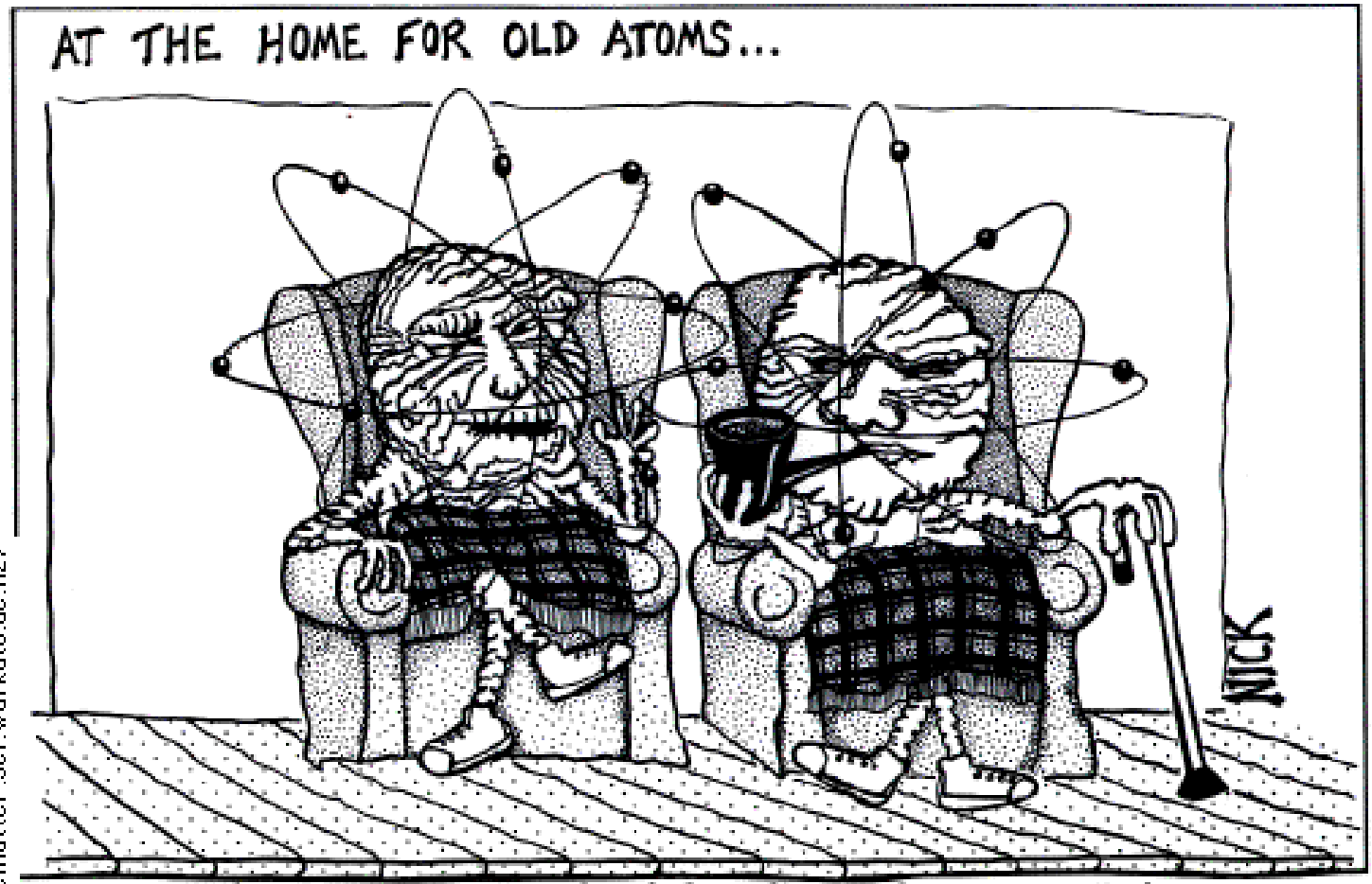
- Rama Murthy, van Westrenen, Fei, Nature 423 (2003)
- Gessmann, Wood, Earth Planet Sci Lett, 200 (2002)
- Lee, Jeanloz, Geophys Res Lett, 30 (2003)
- Dziewonski, Anderson, Phys Earth Plan Int 25, 297 (1981)
- Table of Nuclides: http://atom.kaeri.re.kr/index.html
- Super-K: http://elvis.phys.lsu.edu/svoboda/superk.html
- Vogel, Beacom: arxiv:hep-ph/9903554
- Chooz:arxiv:hep-ex/9906011
- http://arxiv.org/abs/hep-ph/0401221
- http://kamland.lbl.gov/Pictures/
- http://www.greeklandscapes.com/maps/satellite.html
- http://virtual.finland.fi/netcomm/news/showarticle.asp?intNWSAID=27070

Thank you!



"When I was young I used to feel so alive, so dangerous..! In fact, would you believe that I started out life as a Uranium-238 ? Then one day I accidentally ejected an alpha particle, and that's where it all began. Now look at me, a spent old atom of Lead-206. It seems that all my life since then has been nothing but decay, decay, decay...."