Neutrino Oscillation Tomography with PINGU

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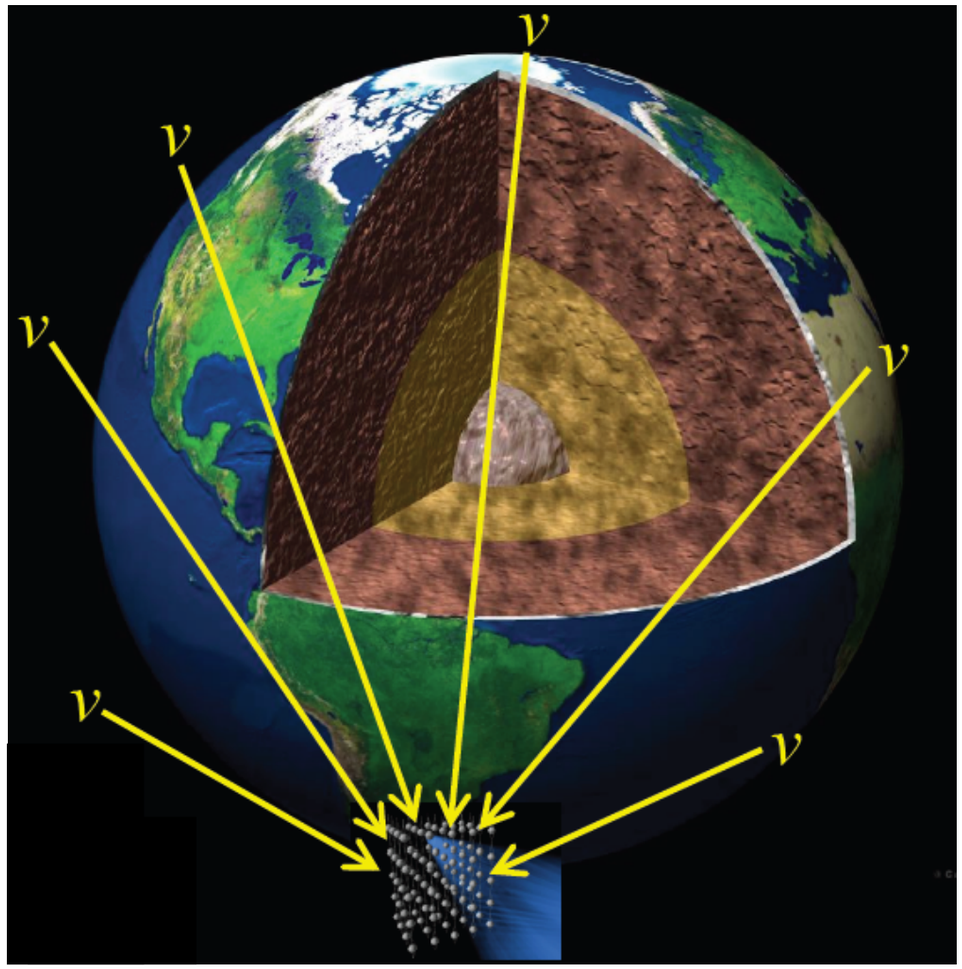
Outline

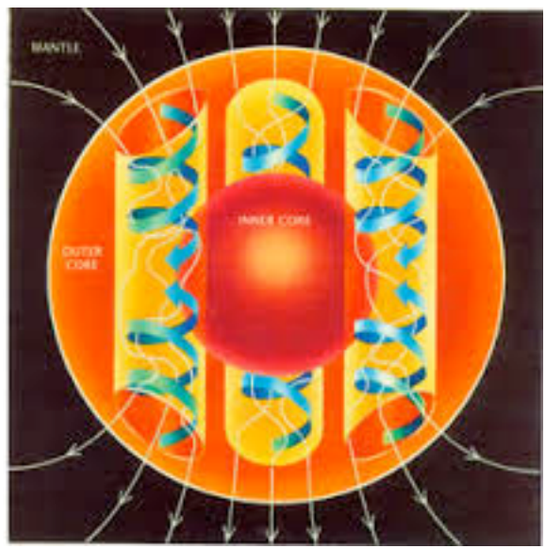
- Motivation
- Methodology of Neutrino Oscillation Tomography
- PINGU Sensitivity and on-going studies
- Conclusions and Plans



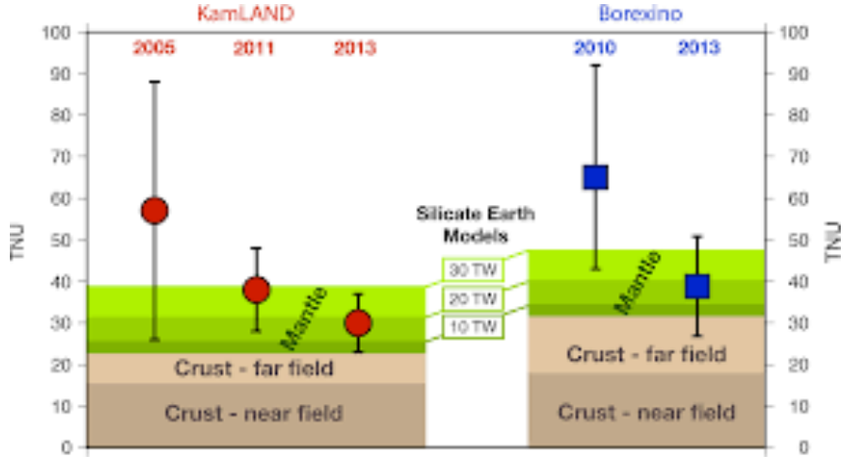
Motivation

Motivation

- New Method to understand inner Earth
  - Inner Earth Composition
    - Light elements in the outer core ?
  - Understand the Geodynamo
- Apply neutrino physics to Earth Science



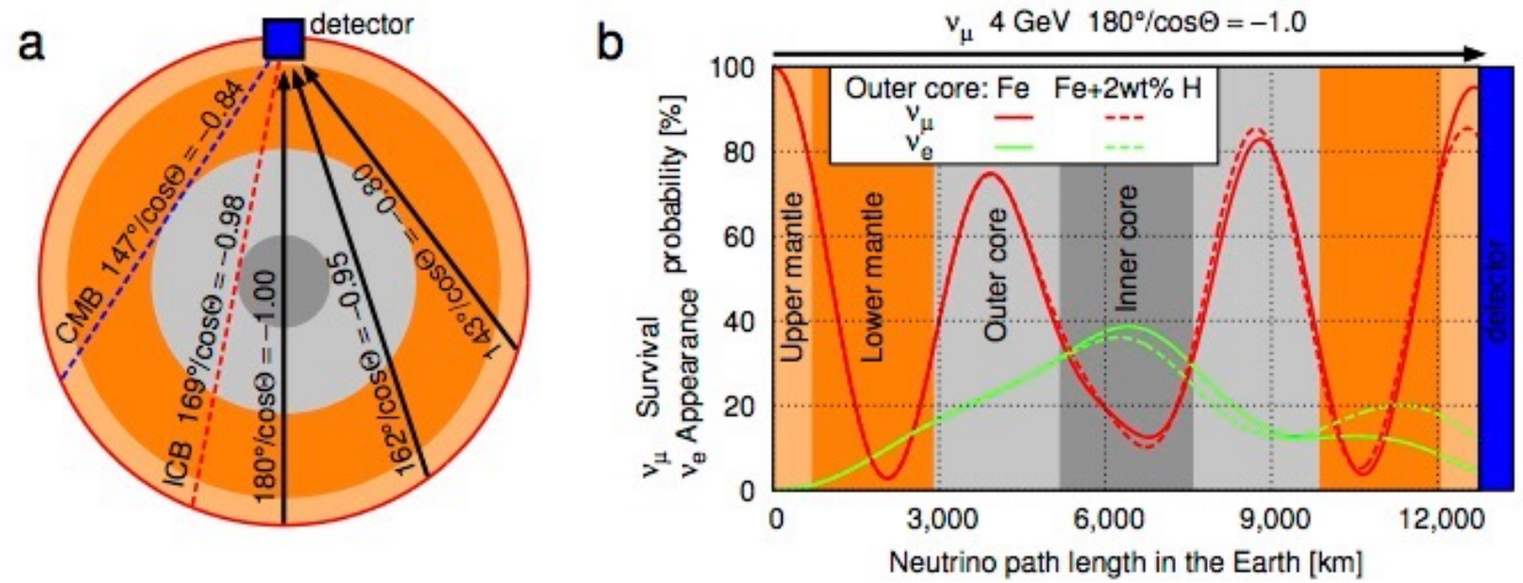
Nature Geoscience;
Volume: 4, 647–651 (2011)



Methodology of Neutrino Oscillation Tomography

Motivation - Methodology

- The Earth **matter density** profile can be determined from **seismic measurements**
- Matter induced **neutrino oscillation** effects however dependent on the **electron density**
- Given a matter density profile the "average" composition (or **Z**/**A**) along the neutrino path can be determined using neutrino signals (Oscillation tomography)



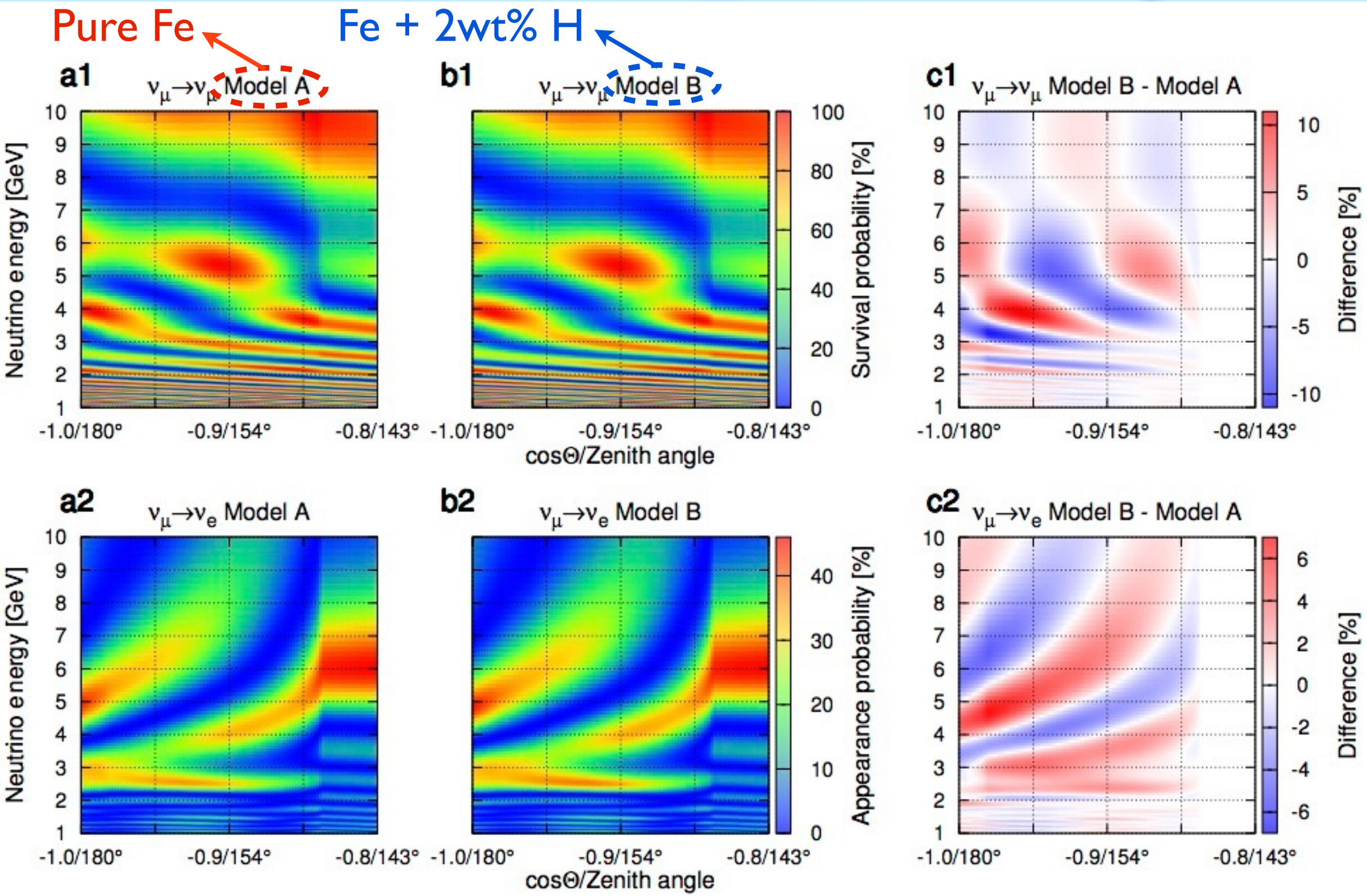
Rott & Taketa 2015

Electron density in core
Y_c=electron/nucleons

corresponding zenith angles for boundaries
Inner Core Boundary (ICB) θ_ν <169° (cos θ_ν < -0.98)
Core Mantle Boundary (CMB) θ_ν <147° (cos θ_ν < -0.84)

Rott & Taketa Scientific Reports (2015)

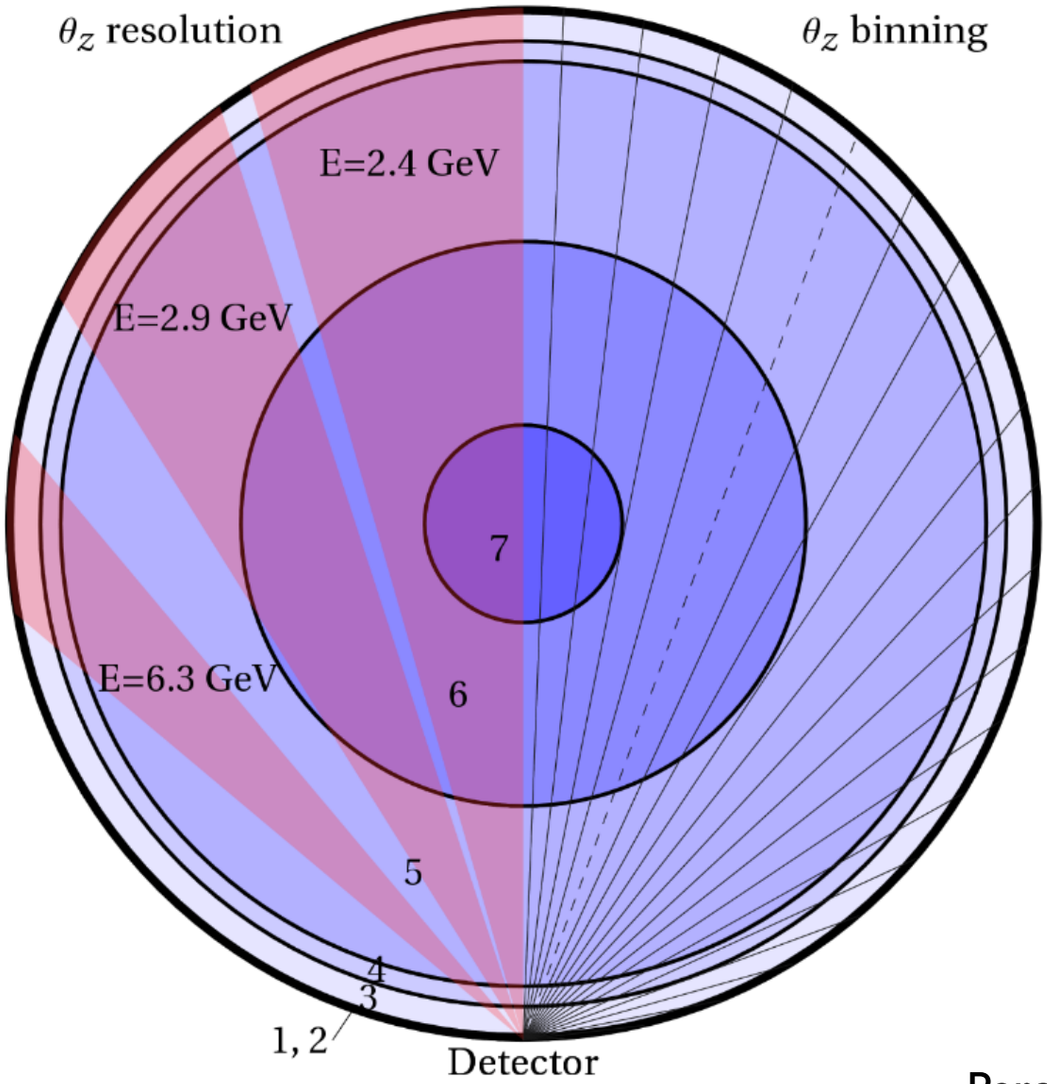
Oscillograms

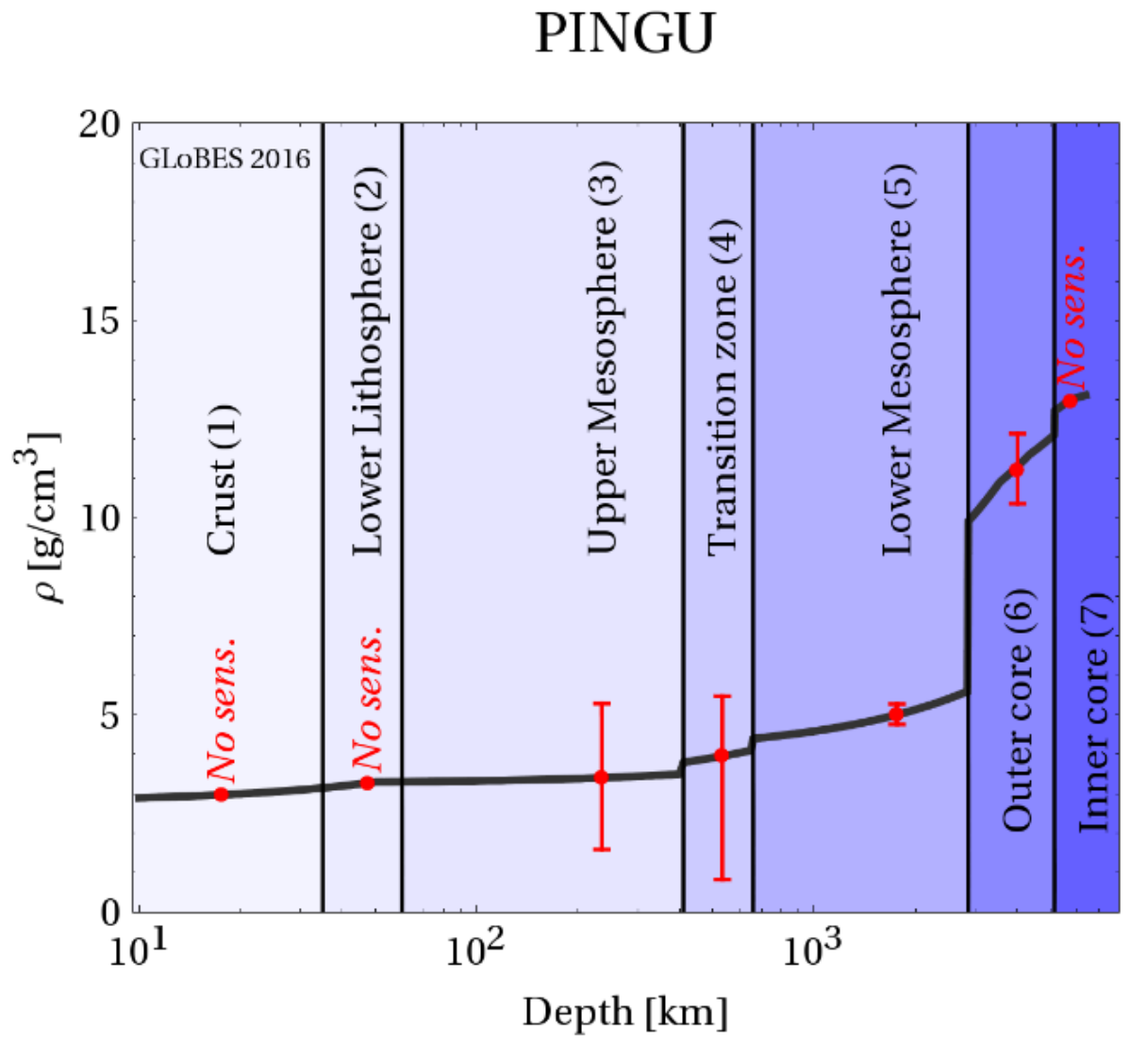


Prospects of density measurements assuming known composition

W. Winter Nucl.Phys. B908 (2016) 250-267

Density measurements





Excellent sensitivities to the lower mantle density and give a robust lower bound on the outer core density

PINGU and ORCA can provide complementary information due to different locations. Seismic measurements show irregular wave propagation zones in the lower mantle

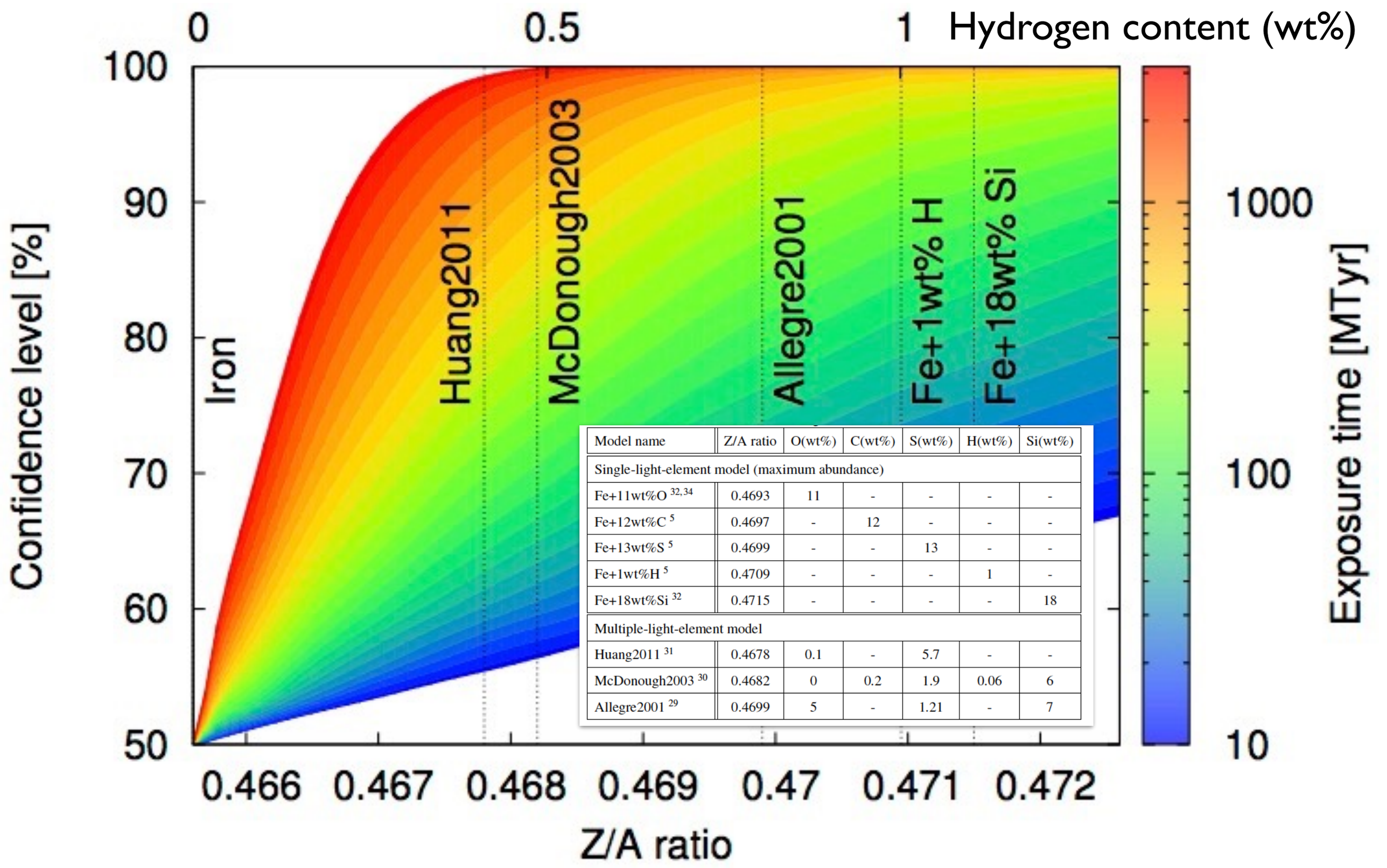
Percentage errors achievable with 10 years of data

	PINGU		ORCA	
Layer	NO	IO	NO	IO
Crust (1)	No sens.	No sens.	No sens.	No sens.
Lower Lithosphere (2)	No sens.	No sens.	No sens.	No sens.
Upper Mesosphere (3)	-53.4/+55.0	No sens.	-51.2/+53.4	-69.1/+52.2
Transition zone (4)	-79.2/+38.3	No sens./+72.2	-61.2/+35.6	-52.7/+45.8
Lower Mesosphere (5)	-5.0/+5.2	-10.5/+11.6	-4.0/+4.0	-4.7/+4.8
Outer core (6)	-7.6/+8.2	-40.2/No sens.	-5.4/+6.0	-6.5/+7.1
Inner core (7)	No sens.	No sens.	-60.8/+32.9	No sens.

Thank you !

Rott & Taketa 2015

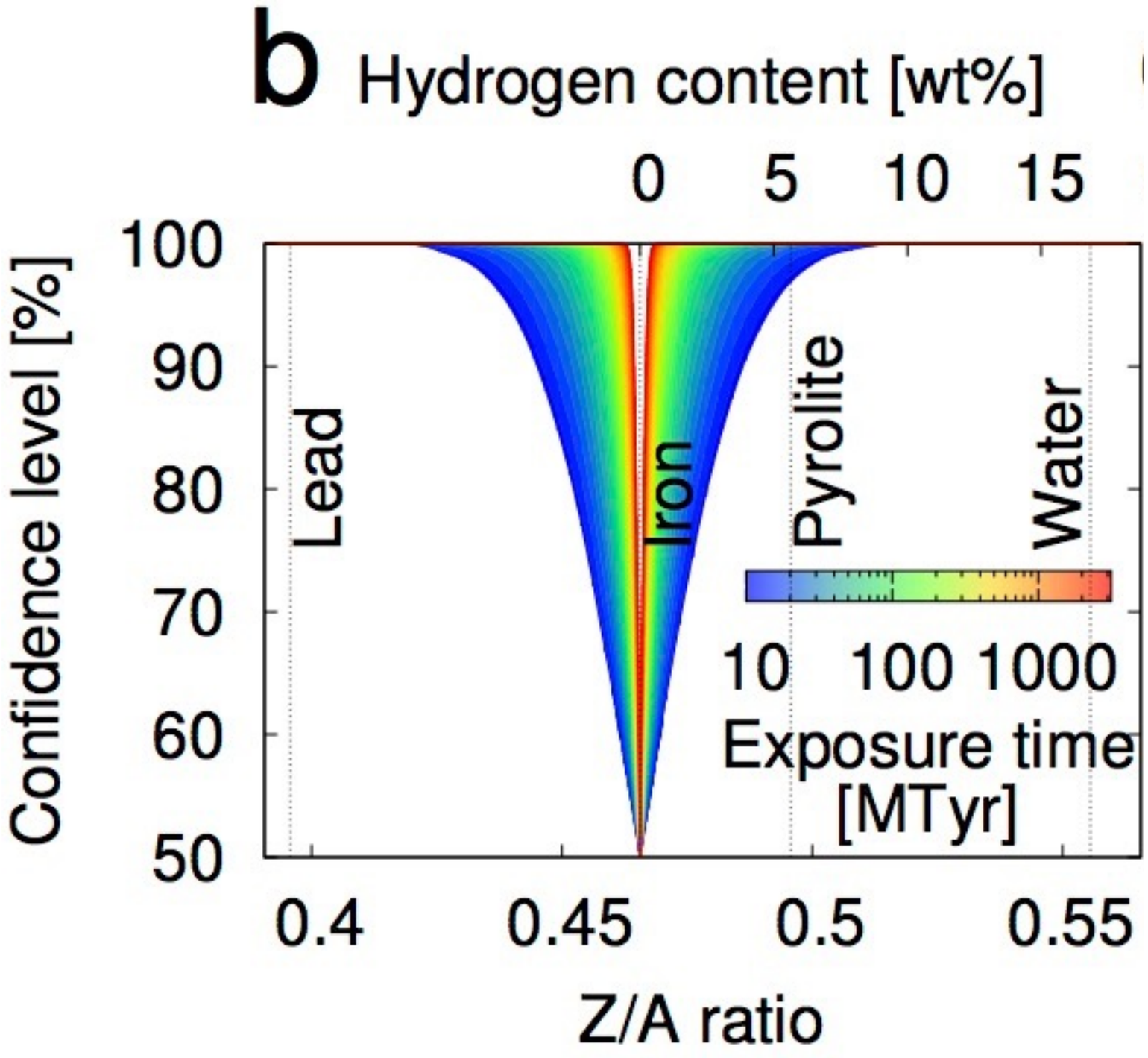
Distinguishing Outer core models



Model name	Z/A ratio	O(wt%)	C(wt%)	S(wt%)	H(wt%)	Si(wt%)
Single-light-element model (maximum abundance)						
Fe+11wt%O [32,34]	0.4693	11	-	-	-	-
Fe+12wt%C [5]	0.4697	-	12	-	-	-
Fe+13wt%S [5]	0.4699	-	-	13	-	-
Fe+1wt%H [5]	0.4709	-	-	-	1	-
Fe+18wt%Si [32]	0.4715	-	-	-	-	18
Multiple-light-element model						
Huang2011 [31]	0.4678	0.1	-	5.7	-	-
McDonough2003 [30]	0.4682	0	0.2	1.9	0.06	6
Allegre2001 [29]	0.4699	5	-	1.21	-	7

Rott & Taketa 2015

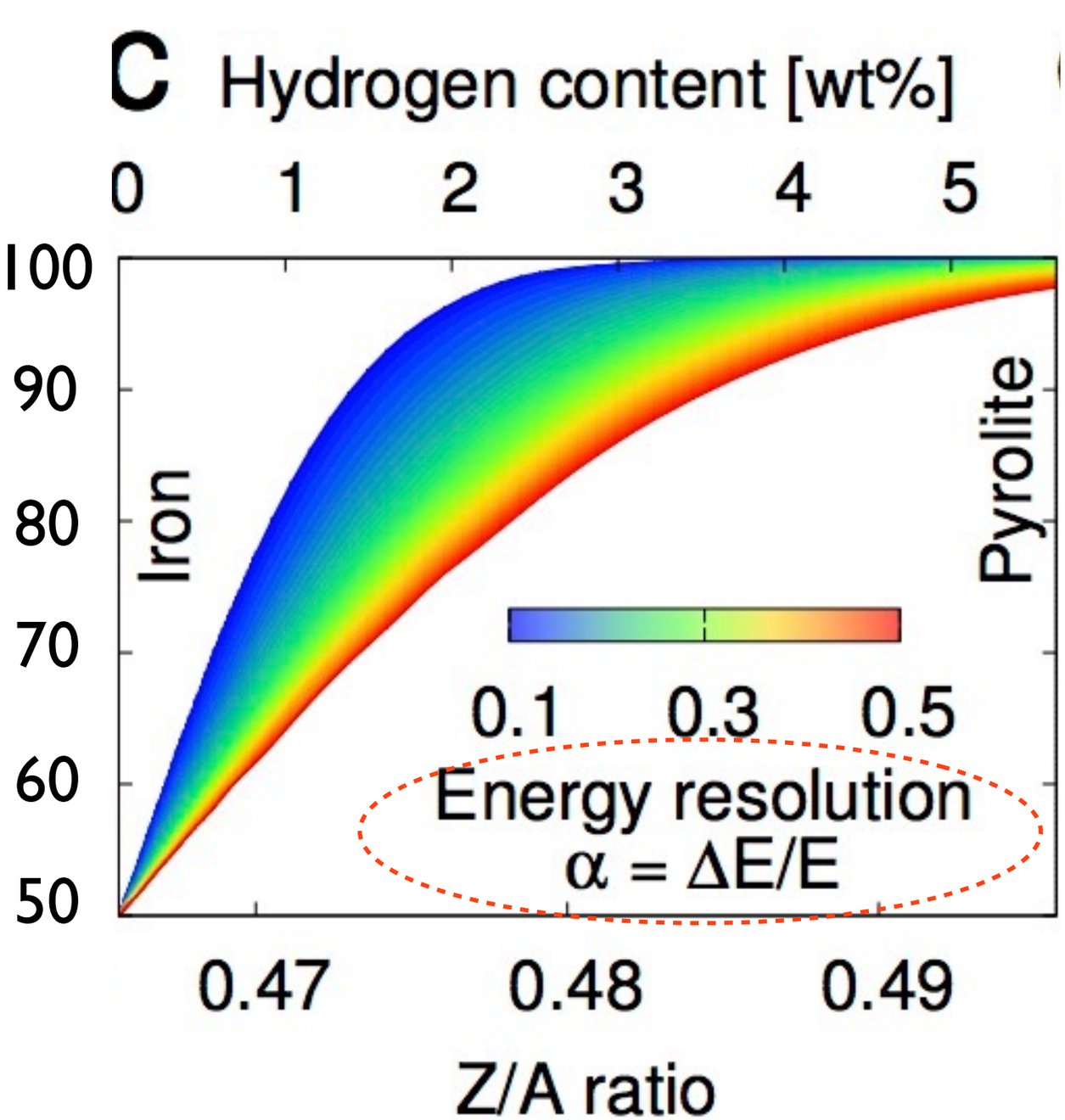
Sensitivity

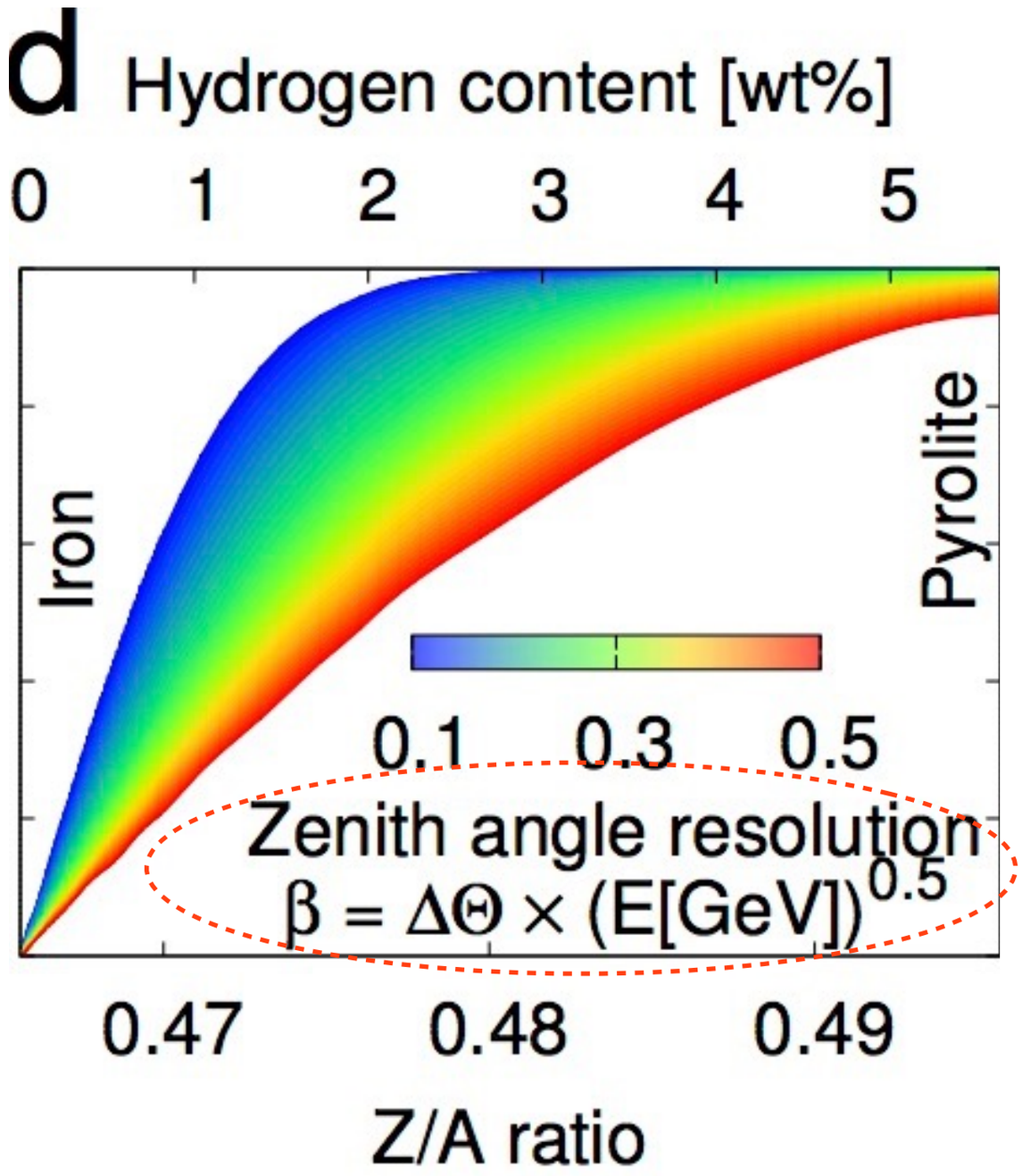


- A few years of PINGU data would yield a few 10MTyrs
- Probe ~2-4wt % hydrogen
- Reject extreme core composition models

How can we increase sensitivity ?

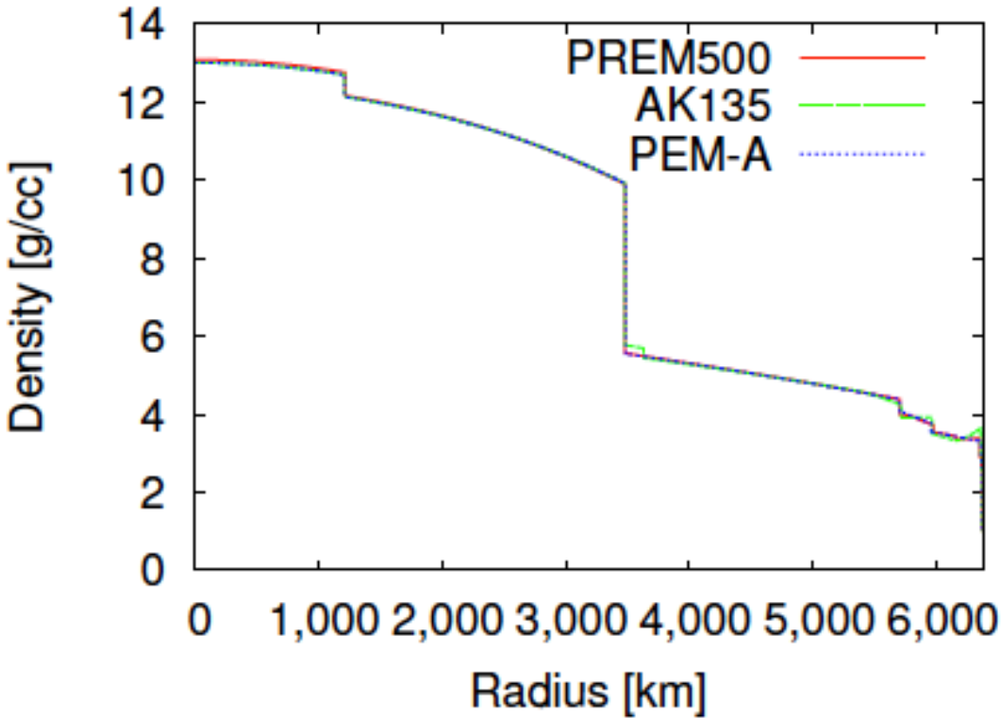
- Dependence on the angular resolution and energy resolution:

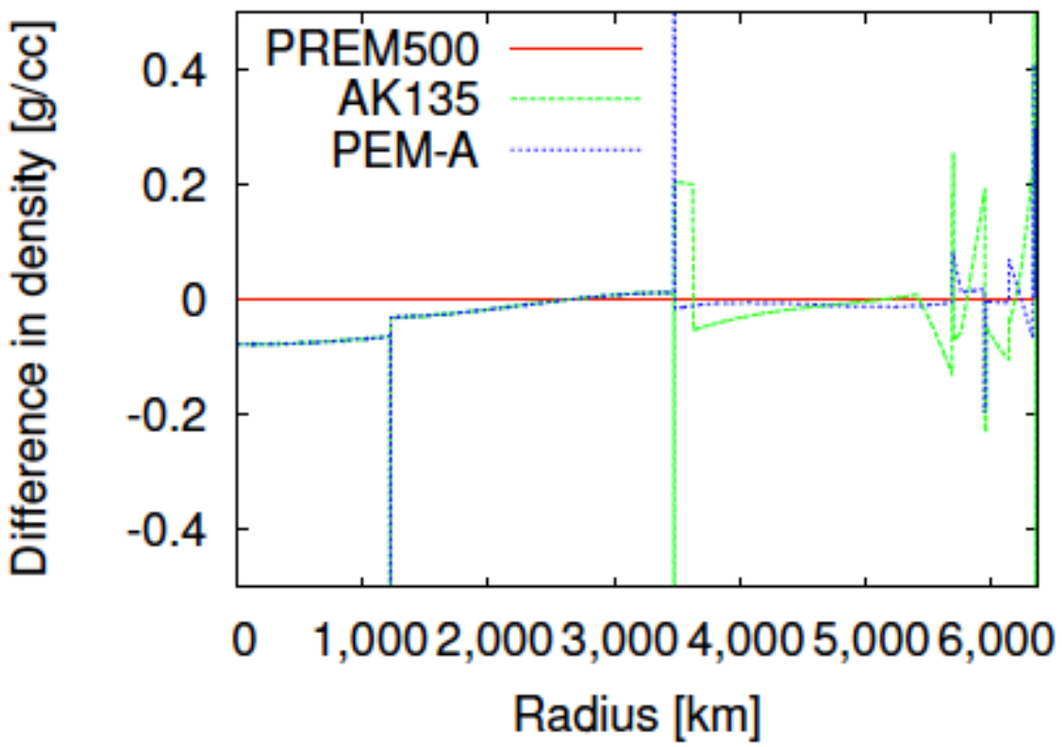


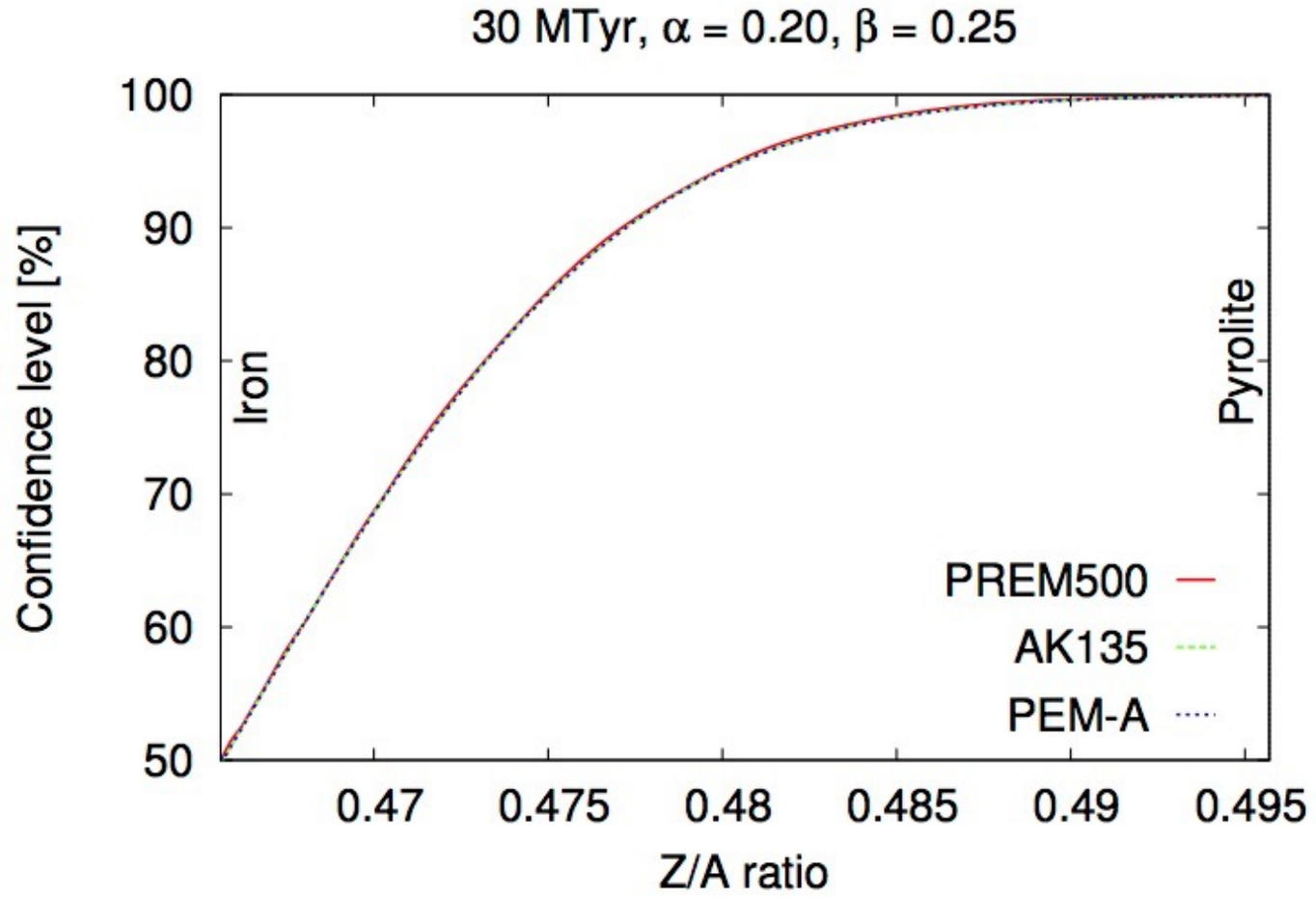


Rott & Taketa 2015

Uncertainty due to Earth model







Uncertainty due to the Earth mass density profile is negligible

PREM500 - Dziewonski, A. & Anderson, D. Preliminary reference Earth model. Physics of the Earth and Planetary Interiors 25, 297–356 (1981).
AK135 - Kennett, B., Engdahl, E. & Buland, R. Constraints on seismic velocities in the earth from travel times. Geophysical Journal International 122, 108–124 (1995).
PREM-A - Dziewonski, A., Hales, A. & Lapwood, E. Parametrically simple earth models consistent with geophysical data. Physics of the Earth and Planetary Interiors 10, 12–48 (1975).