



JUNO 附近的地球中微子 通量估算

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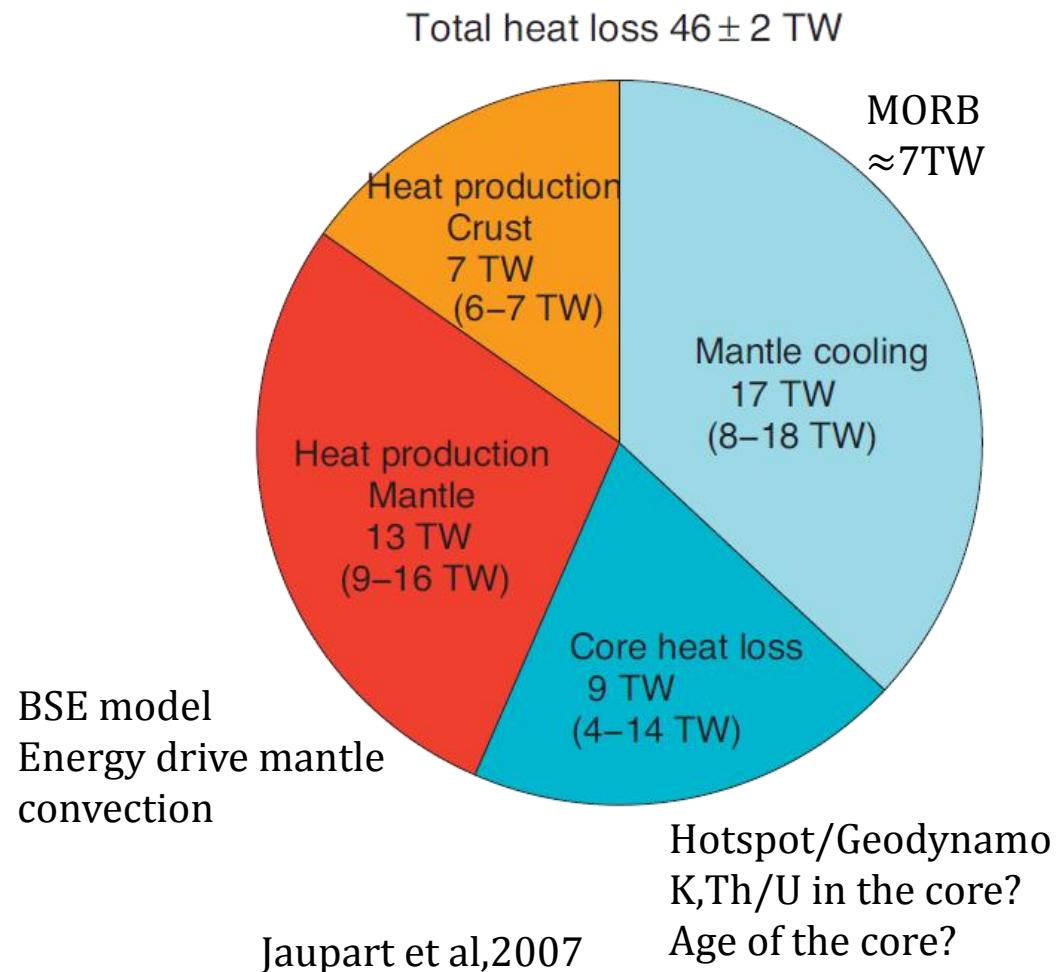
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Outline

- Introduction
- Methods to estimate geoneutrino flux
- Predicting geoneutrino flux with 3 global models and 2 Chinese local models
- Local region contribution study

Introduction

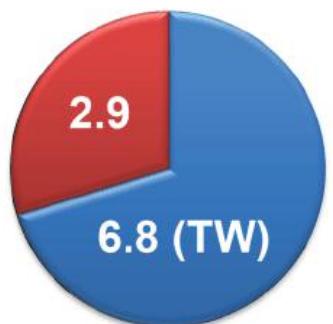


	Stacey and Davis (2008)	Davies (1999)	Jaupart et al. (2007) range (preferred value)
Total heat loss	44	41	46
Crustal heat production	8	5	6–8 (7)
Mantle heat production	20	12–28 ^b	11–15 (13)
Crust-mantle differentiation	0.6	0.3	0.3
Gravitational (thermal contraction)	3.1		
Tidal dissipation		0.1	0.1
Core heat loss	3.5	5	6–14 (8)
Mantle cooling	8.0	9 ^a	9–23 (18) ^c

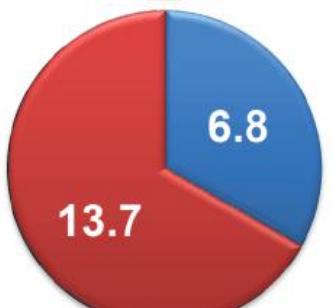
- a. Mantle cooling is fixed.
- b. Lower mantle heat production is variable and adjusted to balance the other terms in the budget.
- c. Mantle cooling is adjusted to balance the budget.

Heat flux in the Earth

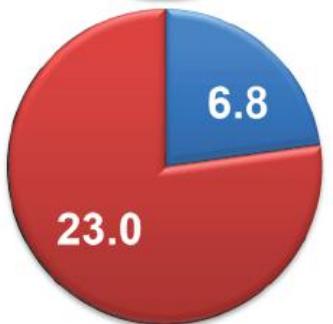
Bulk Silicate Earth Models



Cosmochemical
(10 TW)
(O'Neill & Palme '07)



Geochemical
(20 TW)
(McDonough & Sun '95)



Geodynamic
(30 TW)
(Turcotte & Schubert '02)

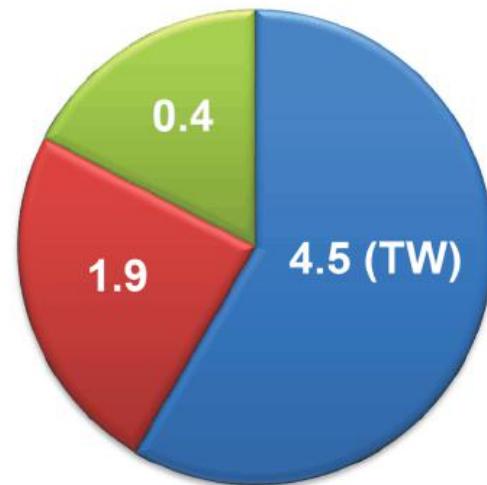
■ Cont. Crust
■ Modern Mantle

Th/U = 4
K/U = 1.4×10^4

Internal Heat?

Continental Crust

(Huang et al 2013)



■ Upper Crust
■ Middle Crust
■ Lower Crust

Geo-neutrinos

- U,Th and ^{40}K in the Earth release heat together with anti-neutrinos in a well fixed ratio:

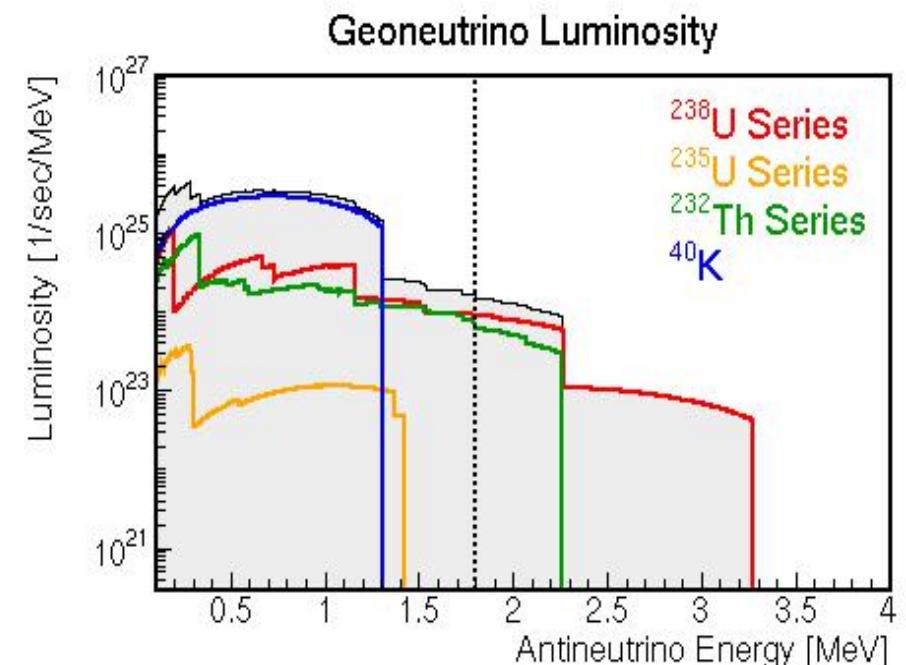
Decay	$T_{1/2}$ [10^9 yr]	E_{max} [MeV]	Q [MeV]	$\varepsilon_{\bar{\nu}}$ [$\text{kg}^{-1}\text{s}^{-1}$]	ε_H [W/kg]
$^{238}\text{U} \rightarrow ^{206}\text{Pb} + 8 \ ^4\text{He} + 6e + 6\bar{\nu}$	4.47	3.26	51.7	7.46×10^7	0.95×10^{-4}
$^{232}\text{Th} \rightarrow ^{208}\text{Pb} + 6 \ ^4\text{He} + 4e + 4\bar{\nu}$	14.0	2.25	42.7	1.62×10^7	0.27×10^{-4}
$^{40}\text{K} \rightarrow ^{40}\text{Ca} + e + \bar{\nu}$ (89%)	1.28	1.311	1.311	2.32×10^8	0.22×10^{-4}

- A fraction of geo-neutrinos from U and Th(not from ^{40}K)are above threshold for inverse beta

$$\bar{\nu} + p \rightarrow e^+ + n - 1.8 \text{ MeV}$$

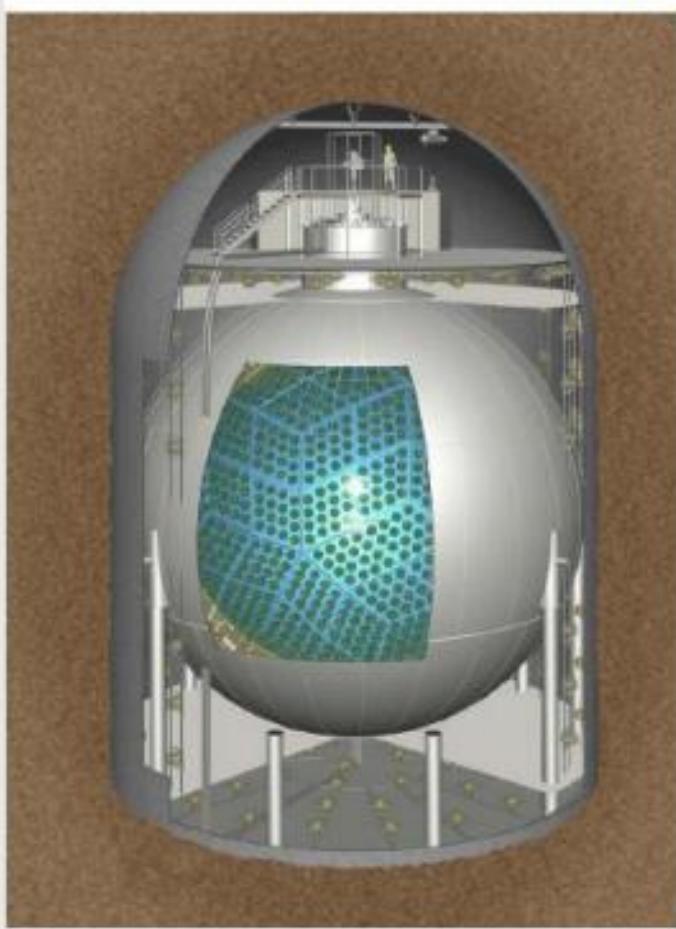
- Different components can be distinguished by energy spectra

Geo-neutrinos: anti-neutrinos from the Earth



First observed in 2005 by KamLAND, then in 2010 by Borexino

KamLAND, Japan (1kt)



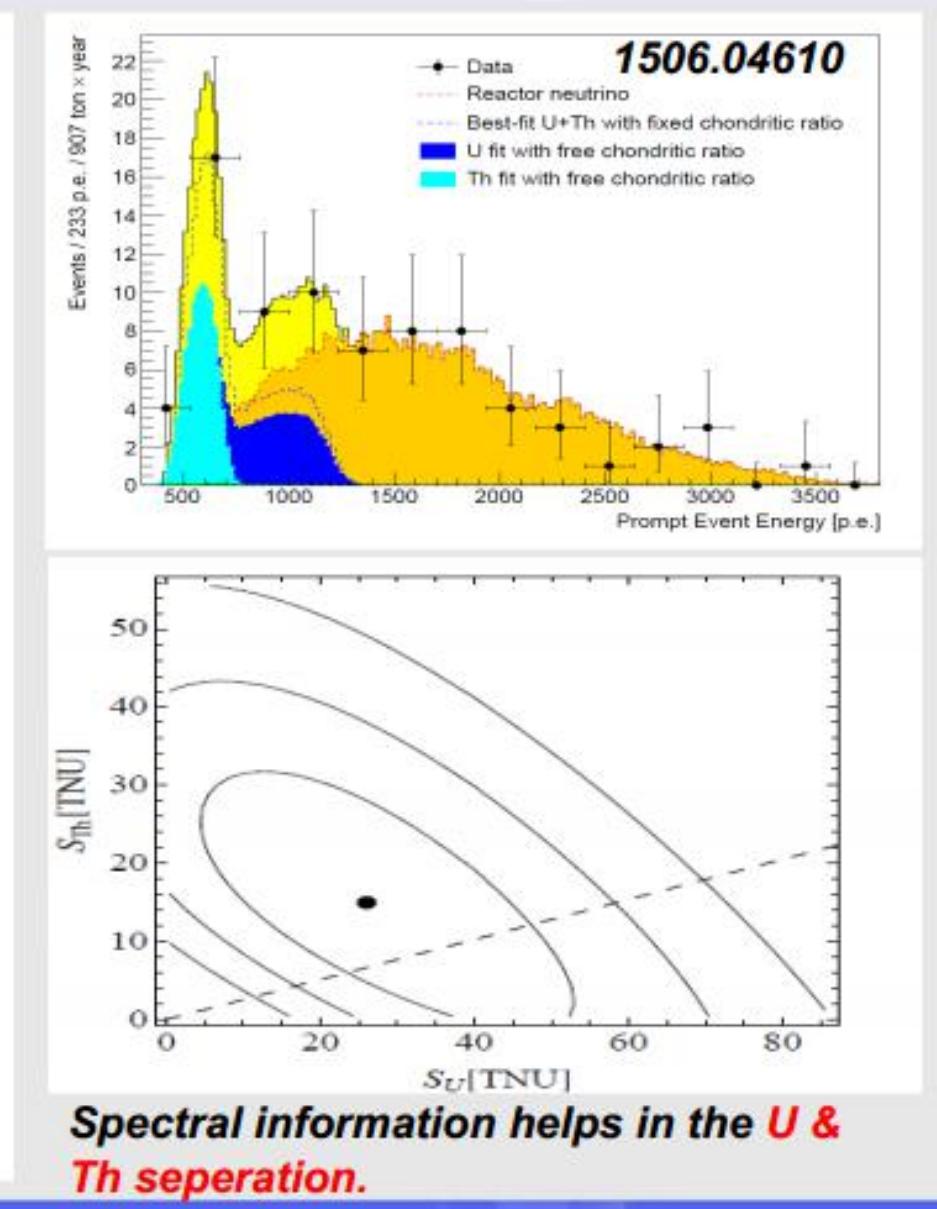
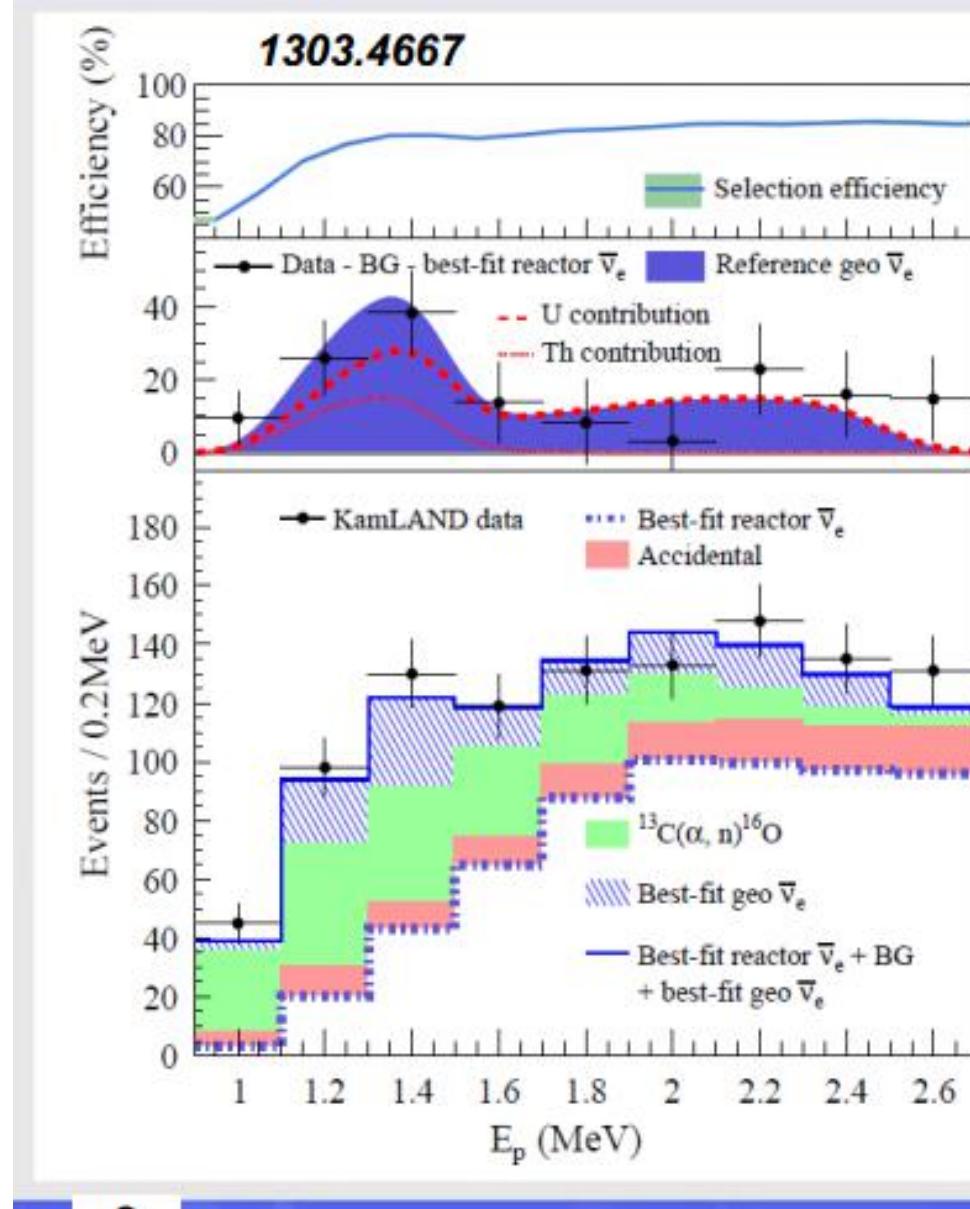
~1 event/30 days

Borexino, Italy (0.6kt)



~1 event/70 days

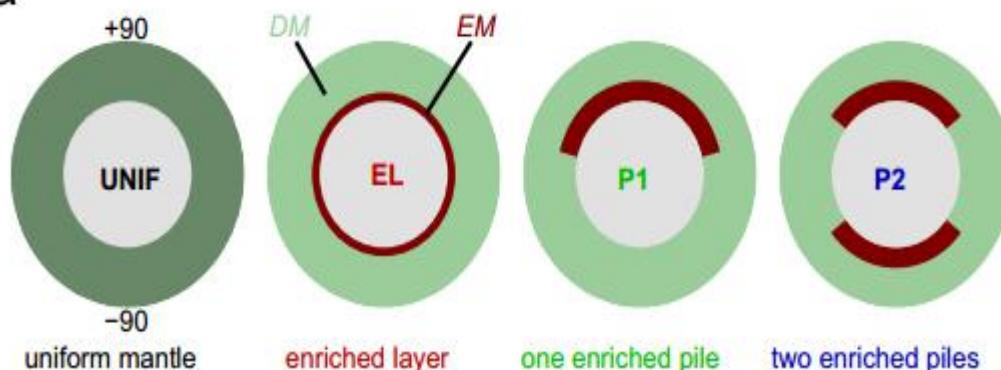
Geoneutrino results of KamLAND and Borexino



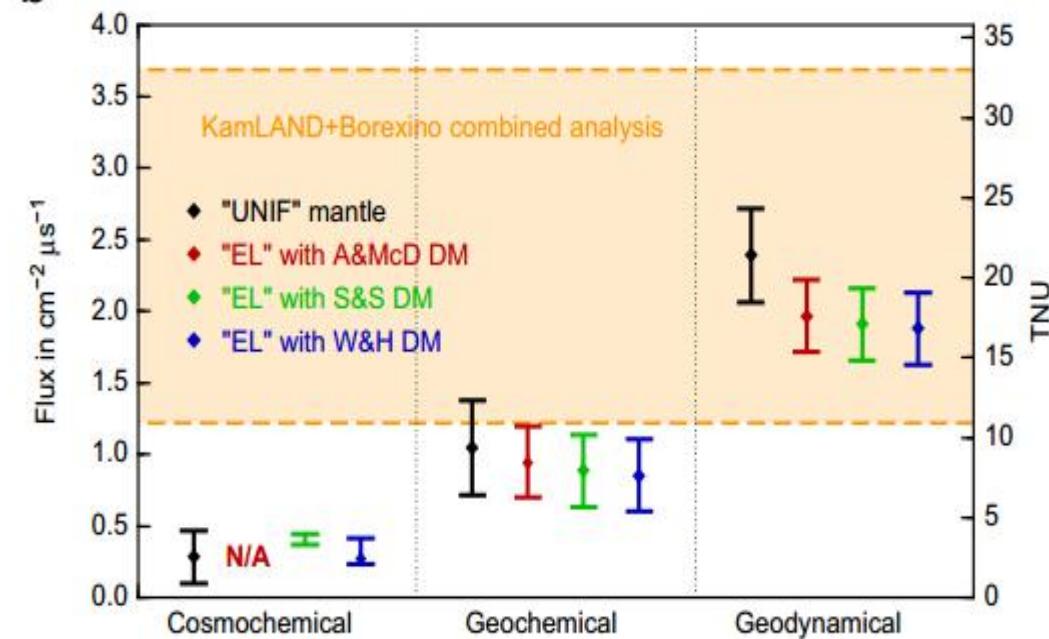
Spectral information helps in the U & Th separation.

Mantle geoneutrino flux

a



b



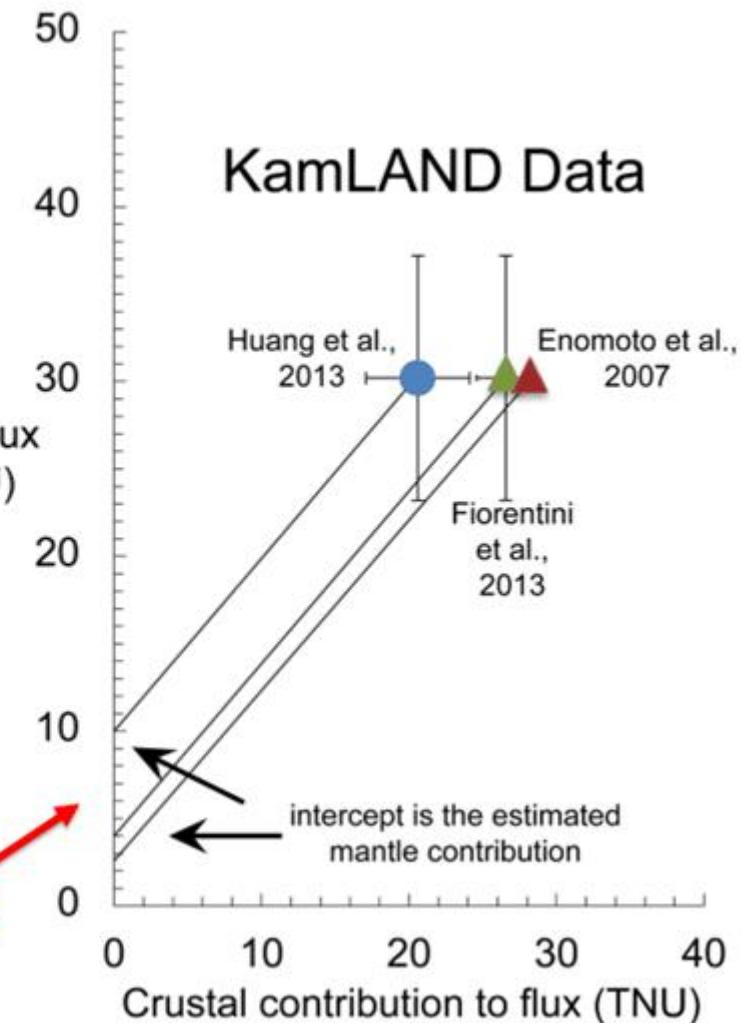
Different Geological models

Y-axis data is strictly from physics

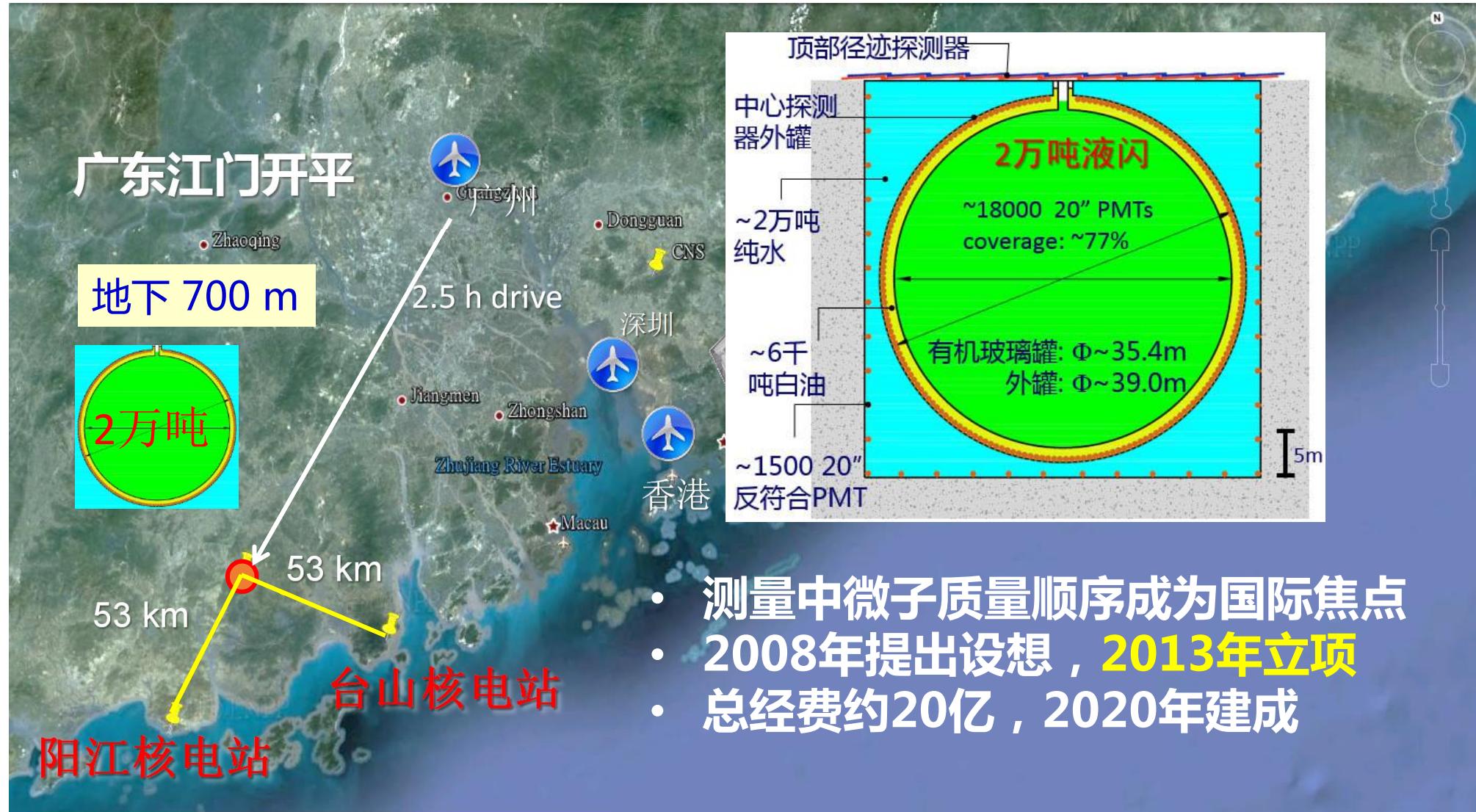
X-axis data is strictly from geology

Intercept is mantle contribution

2, 4 and 10 TNU?



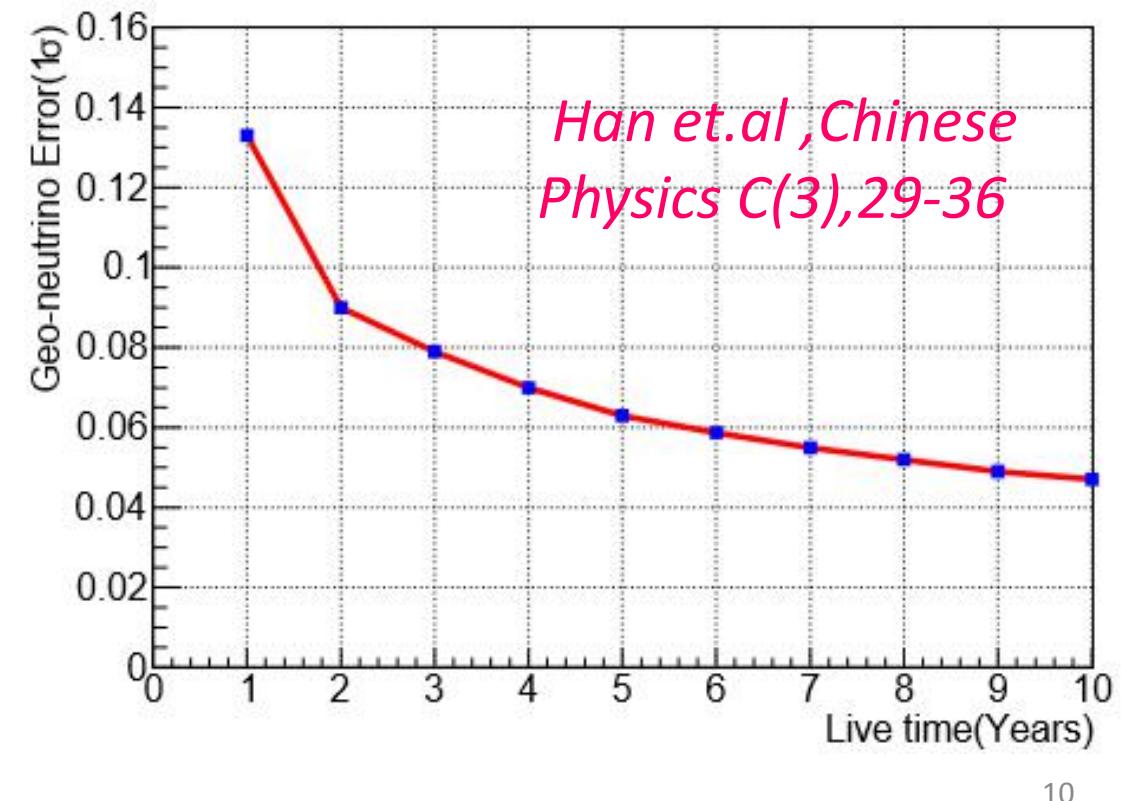
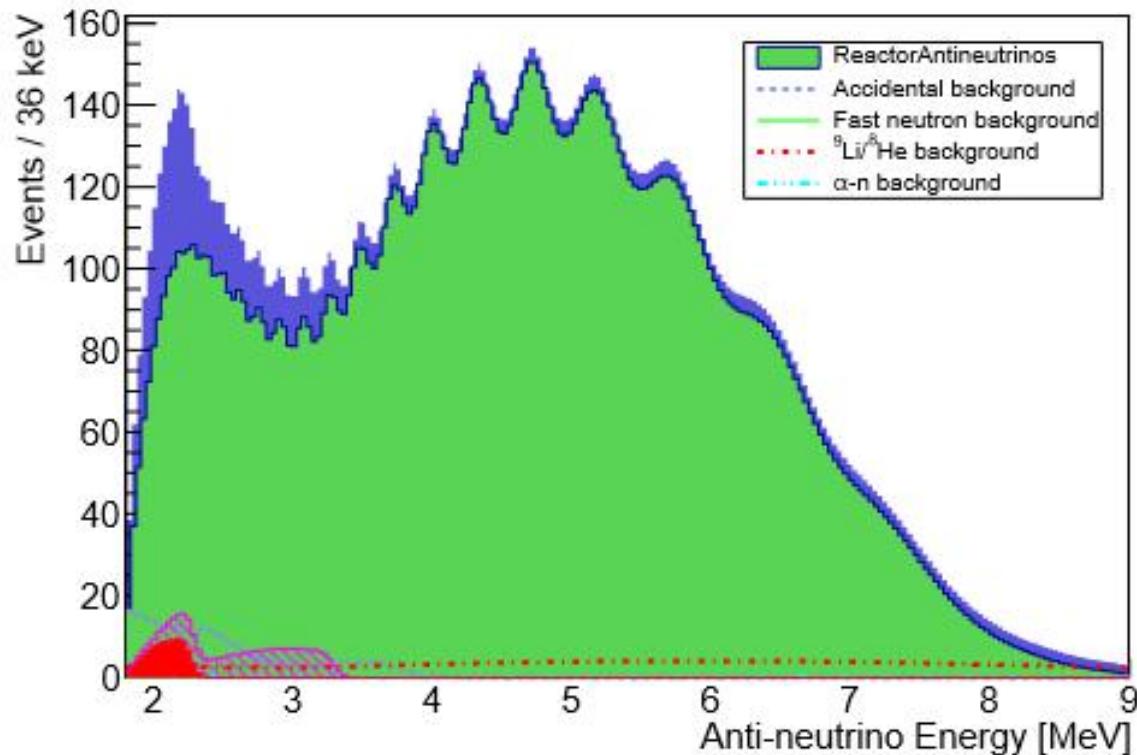
江门中微子实验 (JUNO)



Methods to estimate flux from mantle

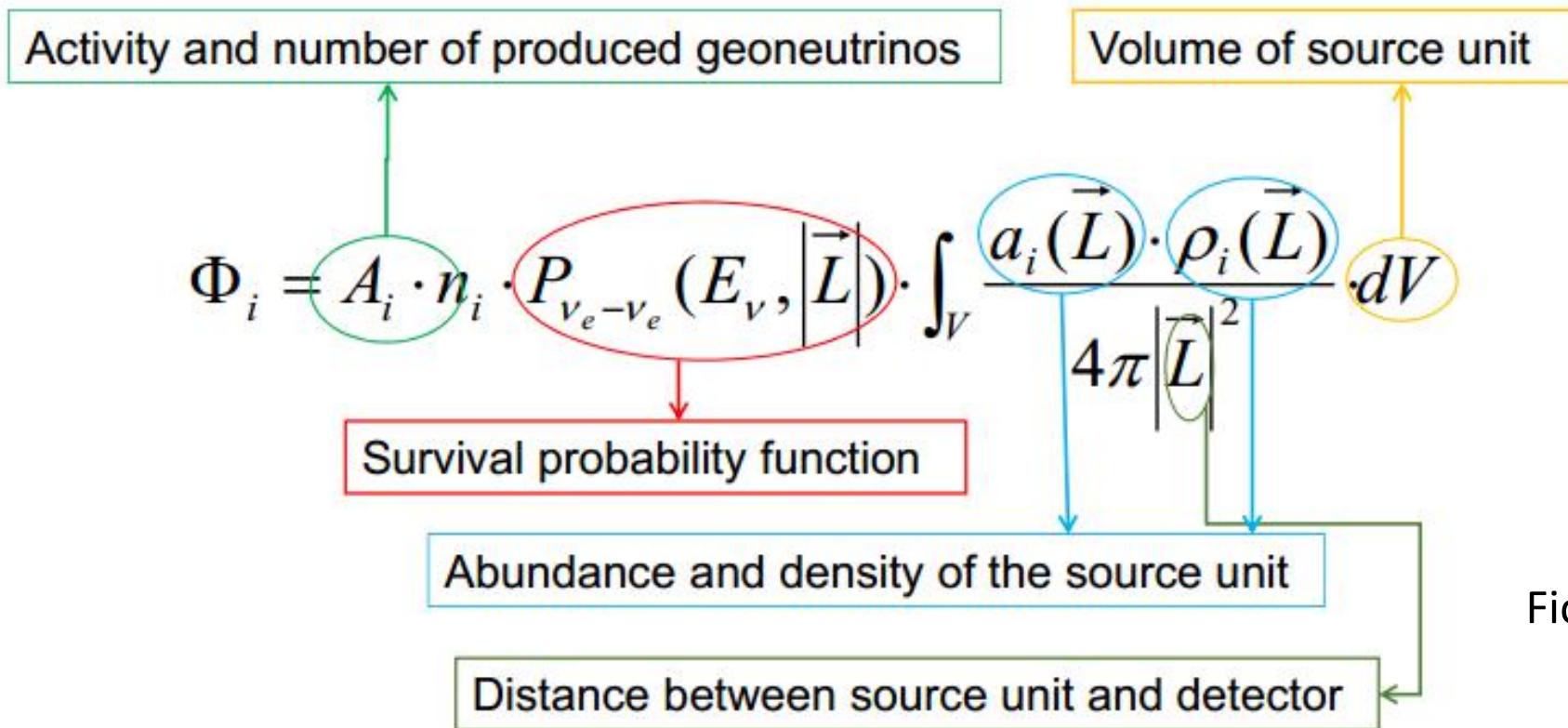
$$R(\text{Mantle}) = R(\text{total, exp.}) - R(\text{Crustal, pred.})$$

With 1.3,5, and 10 years of data, the precision of the geo-neutrino measurement with a fixed chondritic Th/U ratio is 13%, 8%, 6% and 5%, respectively.



Geoneutrino Flux on Earth Surface

$$N_i(x) = N_p t \int_i dE_{\bar{\nu}_e} \epsilon(E_{\bar{\nu}_e}) \sigma(E_{\bar{\nu}_e}) \frac{d\Phi_{\bar{\nu}_e}(x)}{dE_{\bar{\nu}_e}}$$

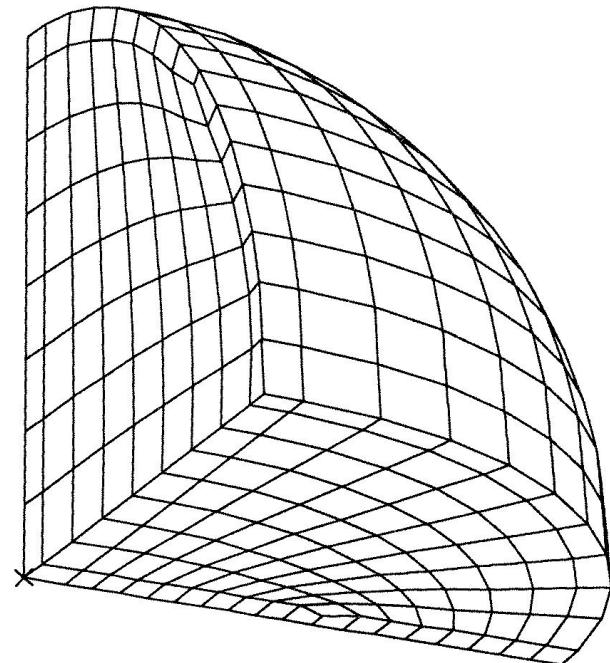
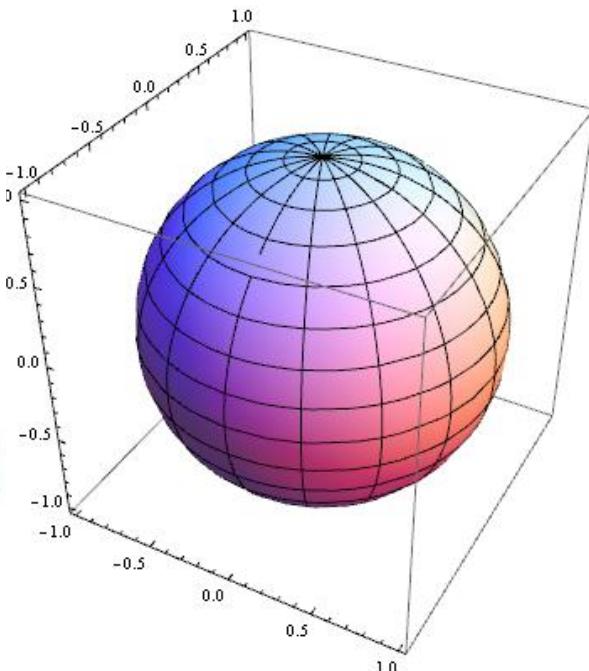
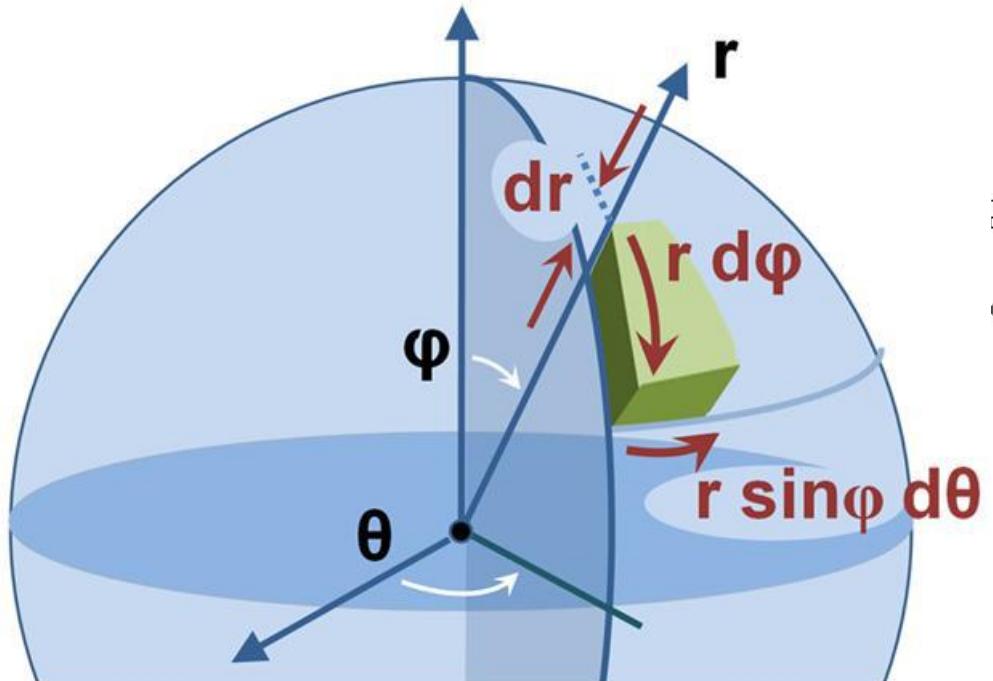
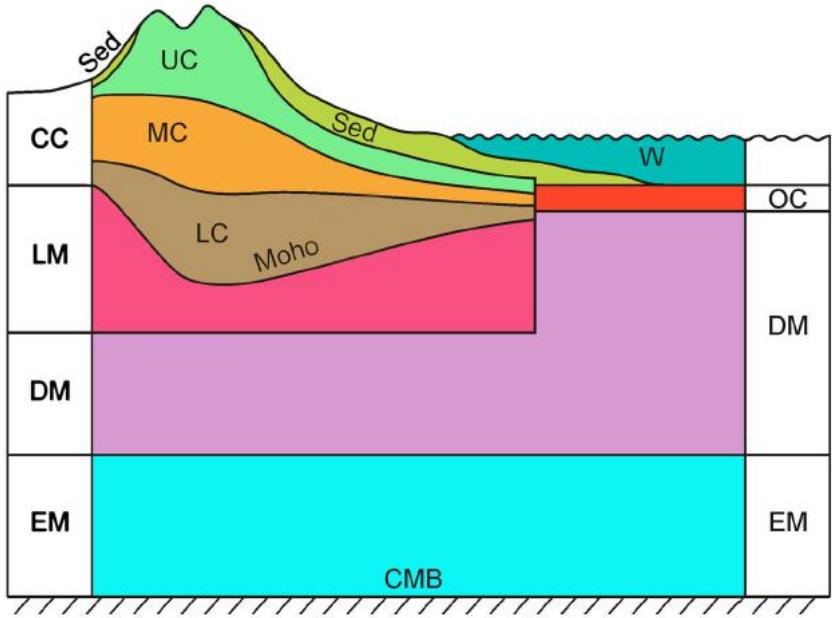


Usman et.al, 2015
Fiorentini et.al, 2007

Earth structure (ρ and L) and chemical composition (a)

Constructing a 3-D reference model Earth

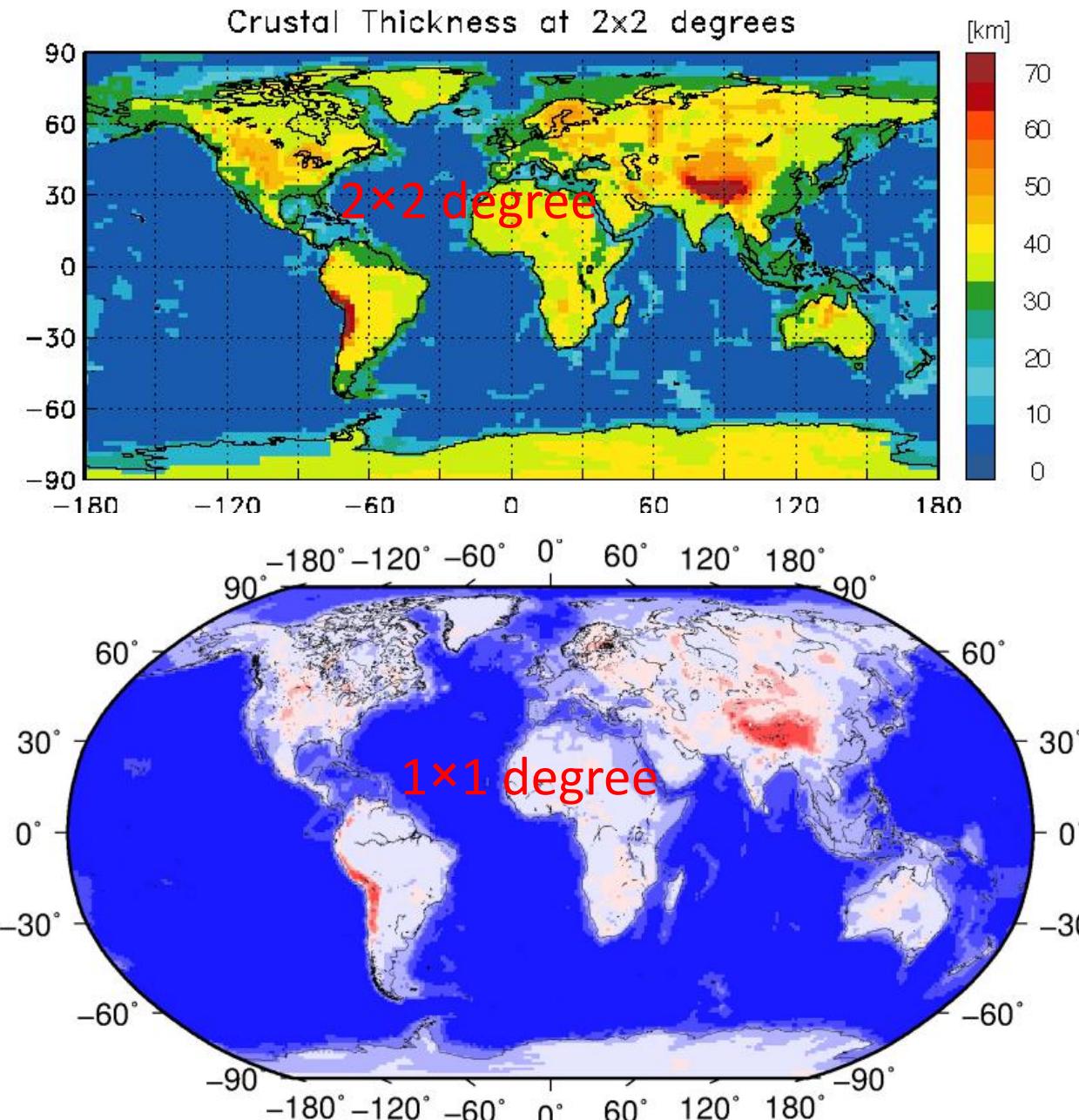
assigning chemical
and physical states to
Earth voxels



Abundance of HPE in each layer of crust

	K (*10 ⁻²)	Th (*10 ⁻⁶)	U (*10 ⁻⁶)	Ref.
Sediment	1.83±7%	8.10±7%	1.73±5%	Plank,2014
Upper Continental Crust	2.32±8%	10.5±10%	2.7±21%	Rudnick&Gao,2014
Middle Continental Crust	1.91±14%	6.5±8%	1.3±31%	Rudnick&Gao,2014
Lower Continental Crust	0.51±30%	1.2±30%	0.2±30%	Rudnick&Gao,2014
Oceanic Crust	(7.16±30%) *10 ⁻⁴	(0.21±30%) *10 ⁻²	(0.07±30%) *10 ⁻²	White&Klein,2014

3 global models



CRUST 2.0

1. water
2. ice
3. soft sediments
4. hard sediments
5. upper crust
6. middle crust
7. lower crust

-21.59	0.15	4.66	3.36
2) continental model			
top of layer (km)	thickness(km)	VP	VS
0.65		1.50	0.00
0.57		3.81	1.94
0.41		2.42	1.17
-0.31		3.81	2.01
-1.14		6.13	3.54
-14.02		6.52	3.67
-26.63		7.09	3.93
-37.51		8.15	4.67
..	

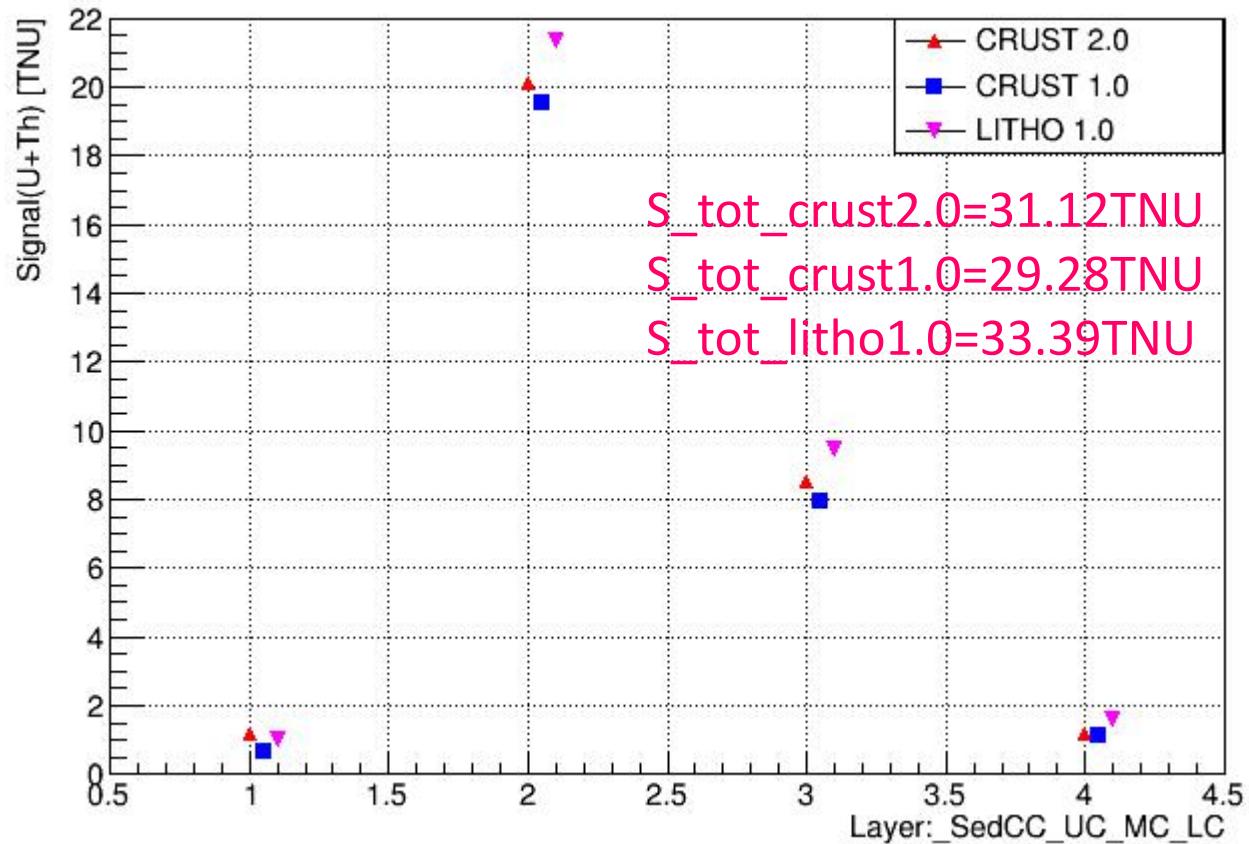
LITHO 1.0

CRUST 1.0

1. water
2. ice
3. upper sediments
4. middle sediments
5. lower sediments
6. upper crust
7. middle crust
8. lower crust
9. lithospheric mantle (lid)
10. asthenospheric mantle

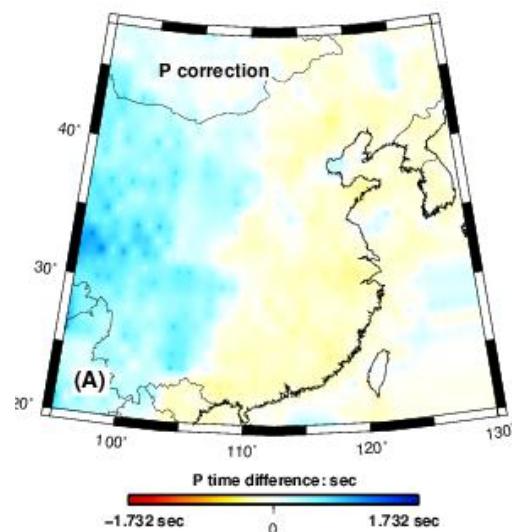
Expect geo-flux with 3 Earth's global models

	Layer	S(U)	S(Th)	S(U+Th)
CRUST 2.0	Sed CC	0.95	0.31	1.26
	UC	15.83	4.27	20.10
	MC	6.34	2.20	8.55
	LC	0.86	0.36	1.21
CRUST 1.0	Sed CC	0.49	0.16	0.65
	UC	15.38	4.15	19.52
	MC	5.92	2.05	7.97
	LC	0.81	0.34	1.14
LITHO 1.0	Sed CC	0.56	0.42	0.98
	UC	16.83	4.55	21.37
	MC	6.99	2.42	9.45
	LC	1.12	0.47	1.59

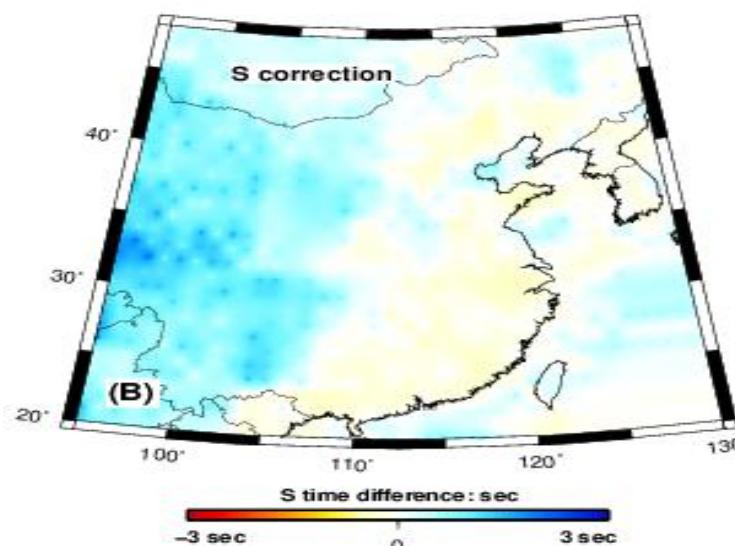
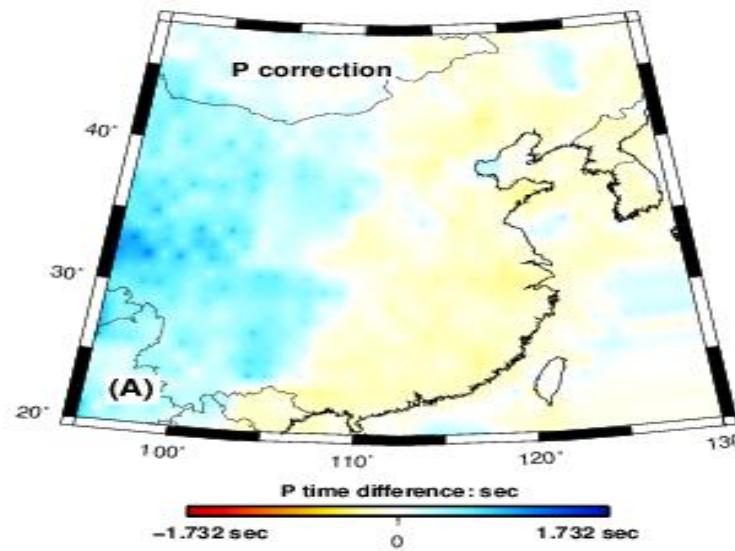
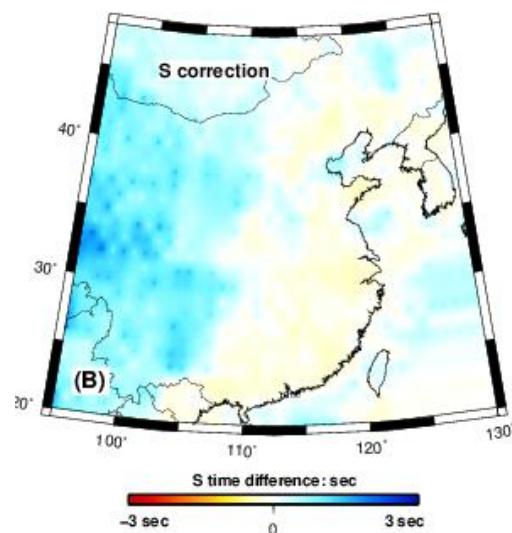


1. Results of LITHO 1.0 is 7% larger than CRUST2.0
2. In the future , we will move to LITHO 1.0

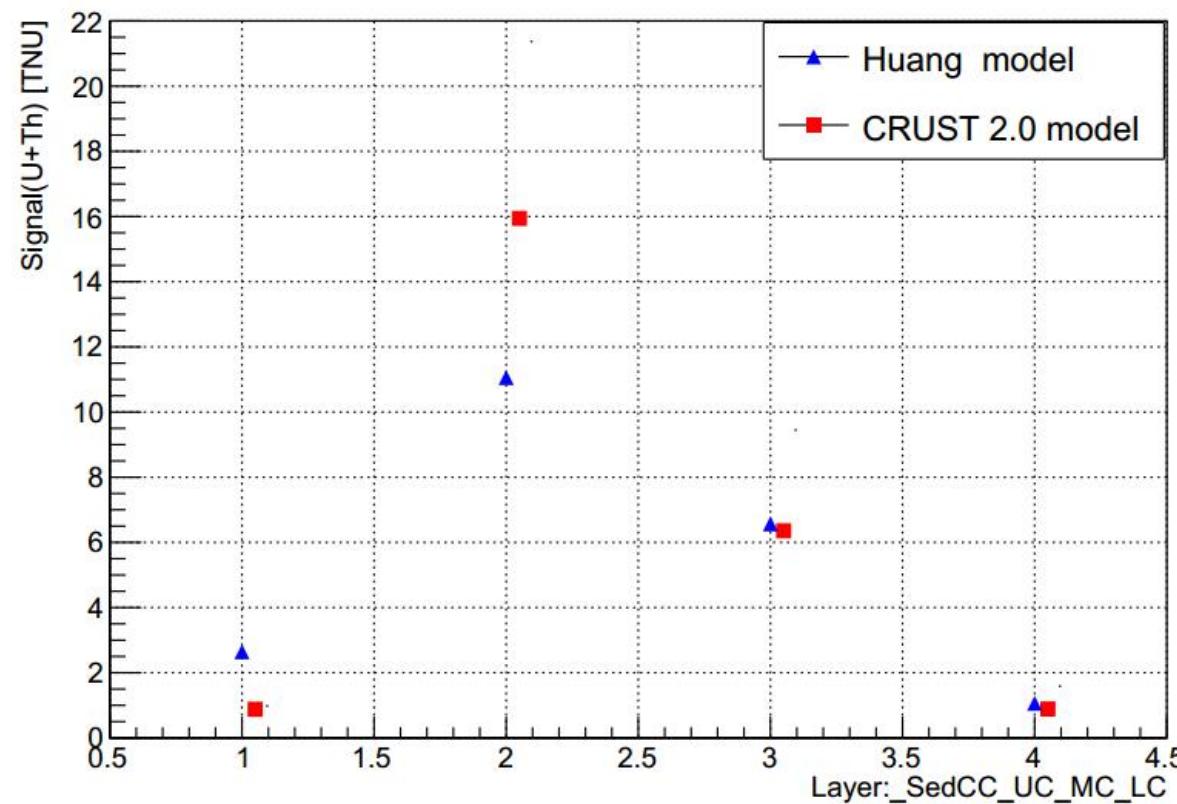
Chinese local models--SunYs and Huang



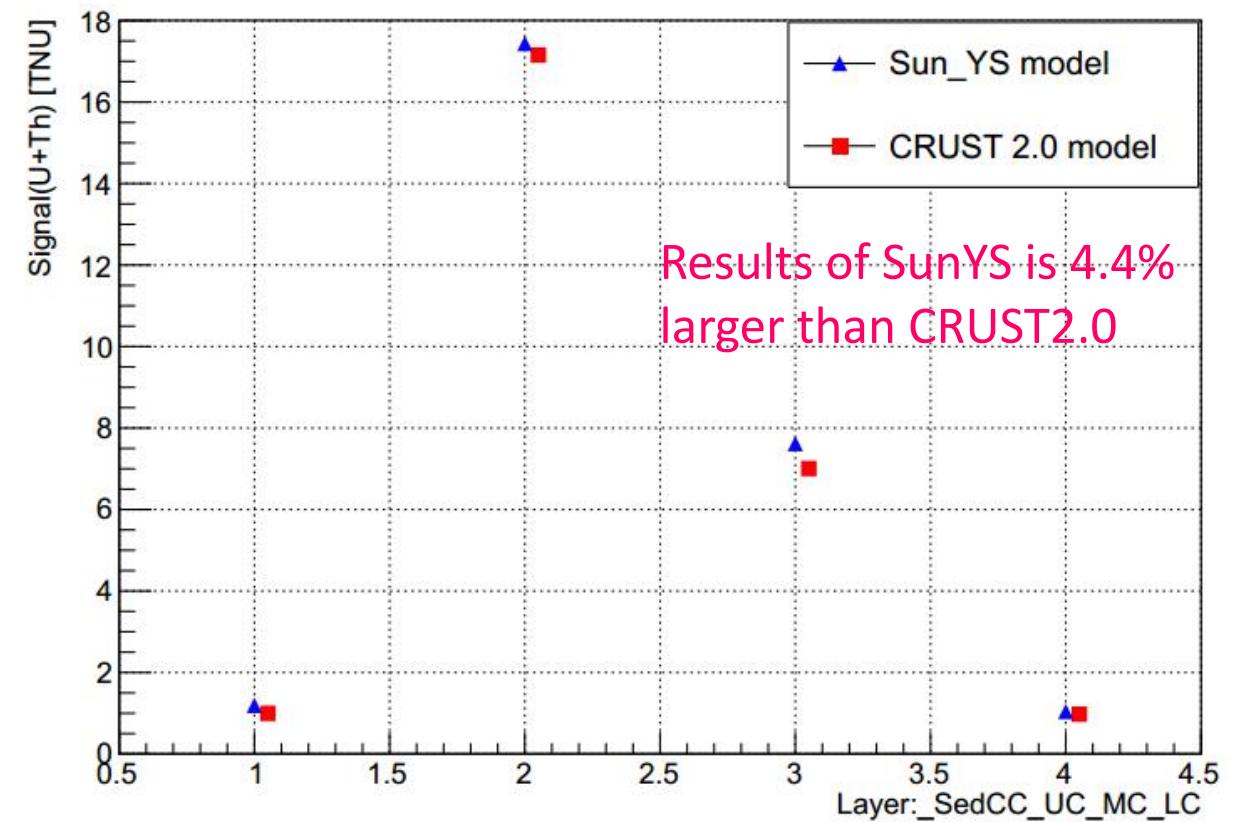
70-130E,20-55N



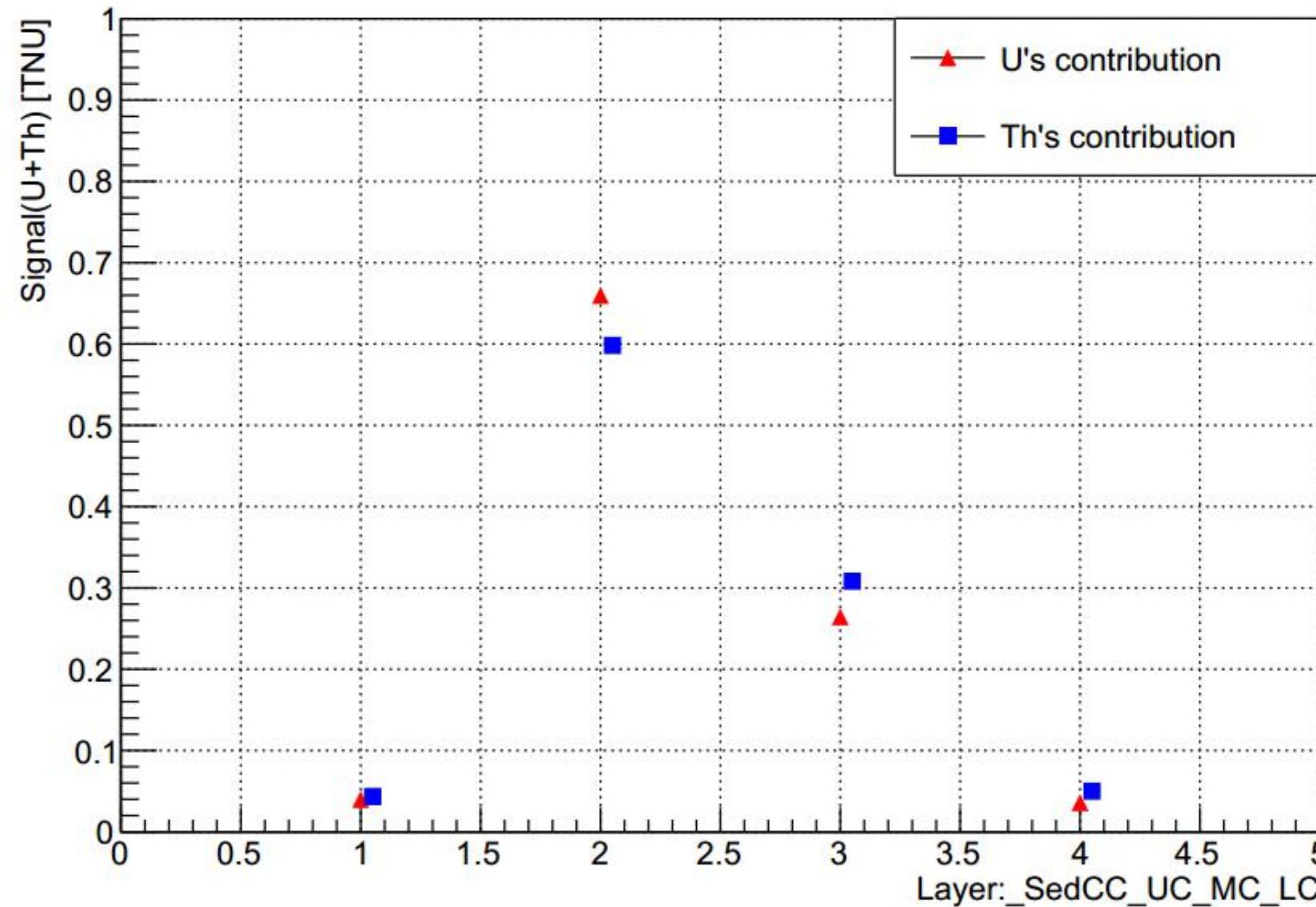
Expect geo-flux with Huang's
models--CRUST 2.0 at same time



Expect geo-flux with SunYS
models--CRUST 2.0 at same area

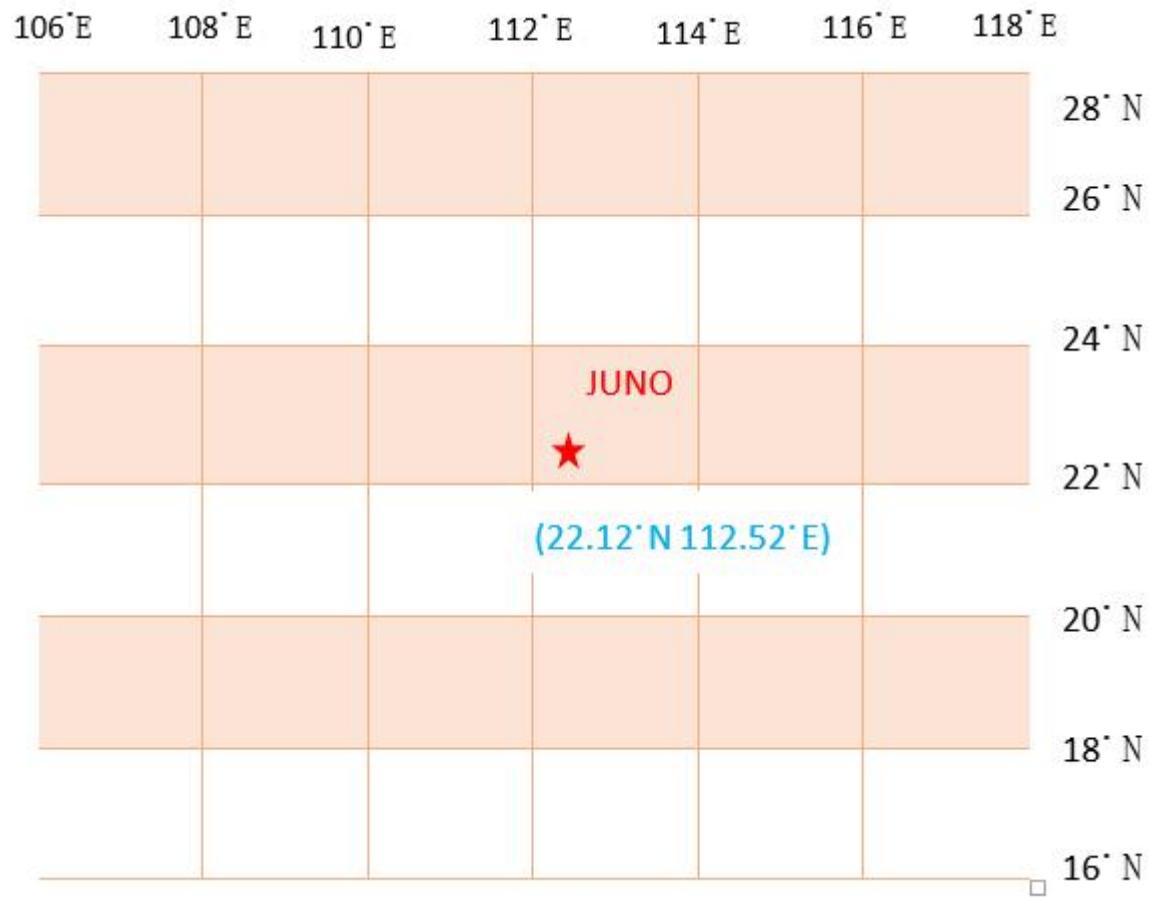


UC's contribution more than 60%, we should be focus more on



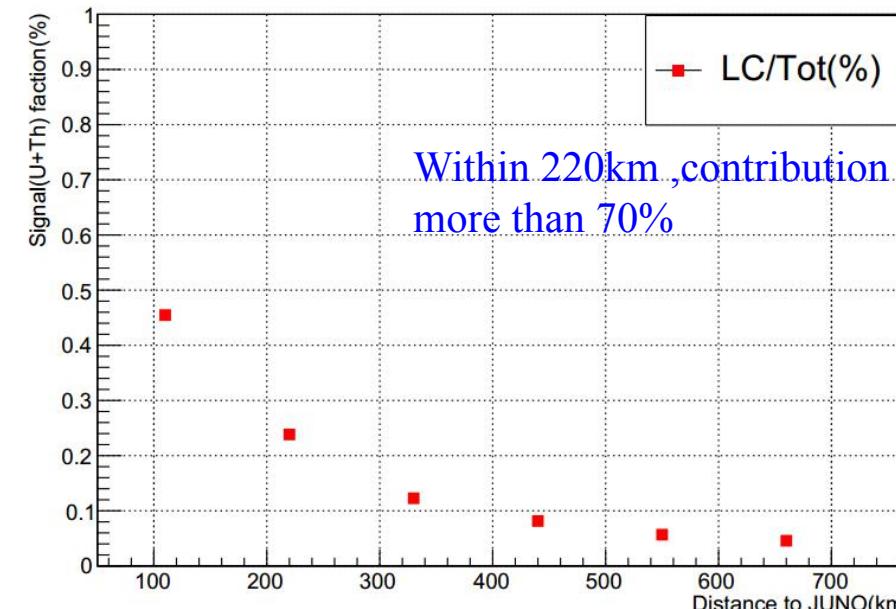
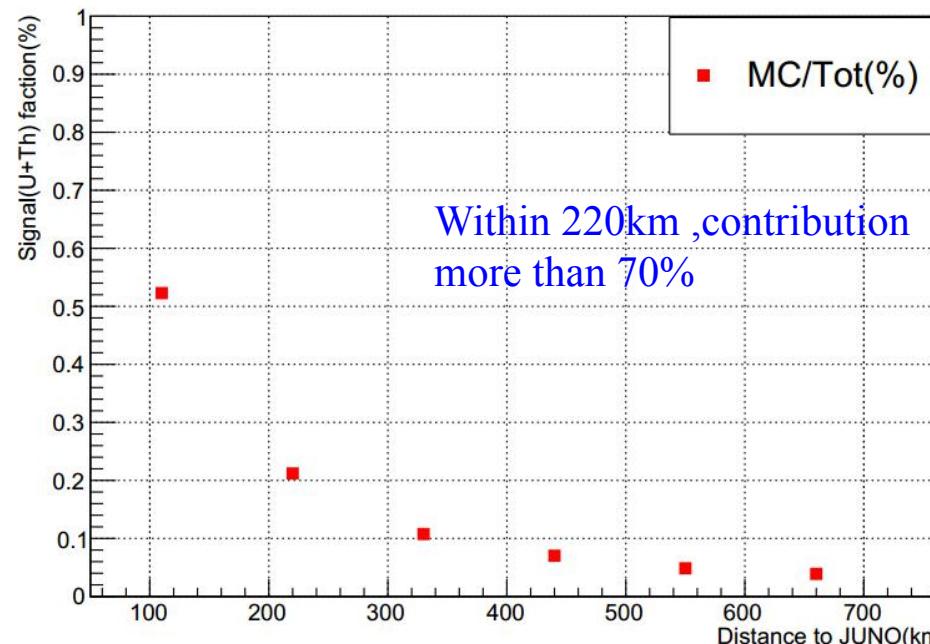
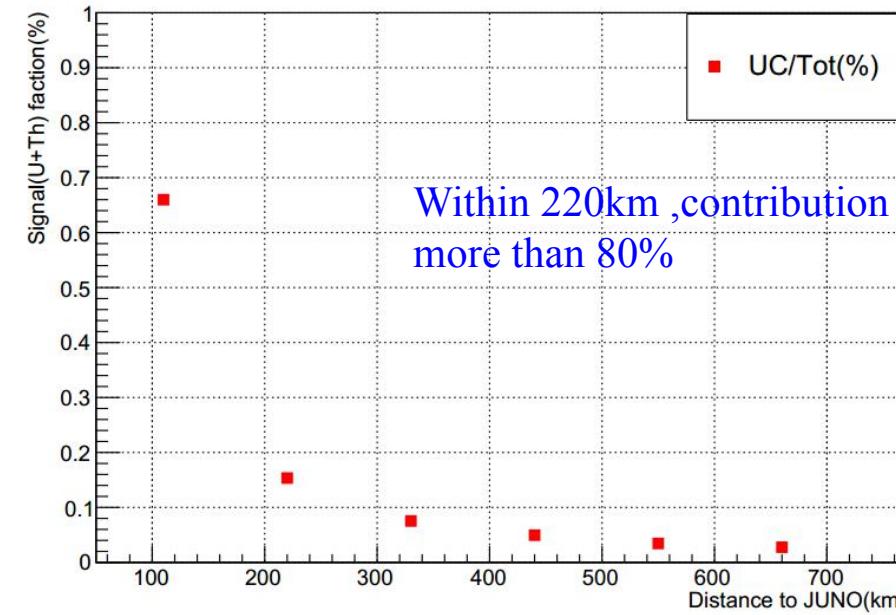
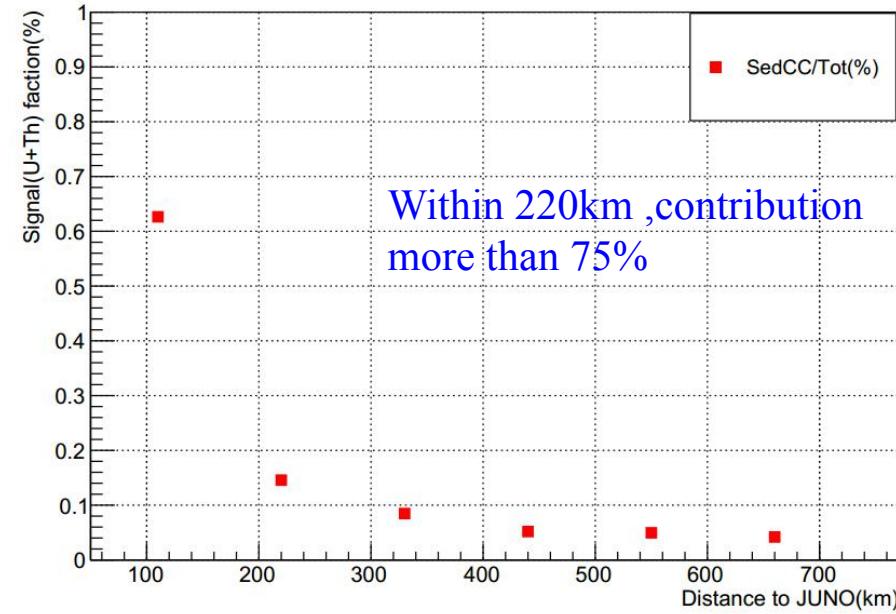
	S($U+Th$)[TNU]	
Sed CC contribution	1.26	4.06%
UC contribution	20.10	64.59%
MC Contribution	8.55	27.45%
LC contribution	1.21	3.90%

Local 660km contribution



	S(U+Th)[TNU]	
Local contribution	21.26	68.30%
Far Field Crust	9.86	31.70%
Crust geo-neutrinos	31.12	

Each 110km area contribution from detector to 660km



Summary

1. Results of LITHO 1.0 is 7% larger than CRUST2.0. In the future , we will move to LITHO 1.0 .
2. Chinese local geological work is essential, include crustal structure and composition.
3. In its 660km range contribute more than 65%, should be focus on.Upper Crust contribute should be focus on.

Thanks !

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