



Solar neutrino at JUNO

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On behalf of JUNO solar working group:

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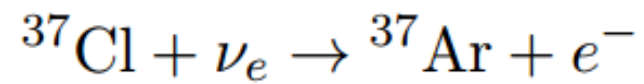
2019-12-6

IHEP

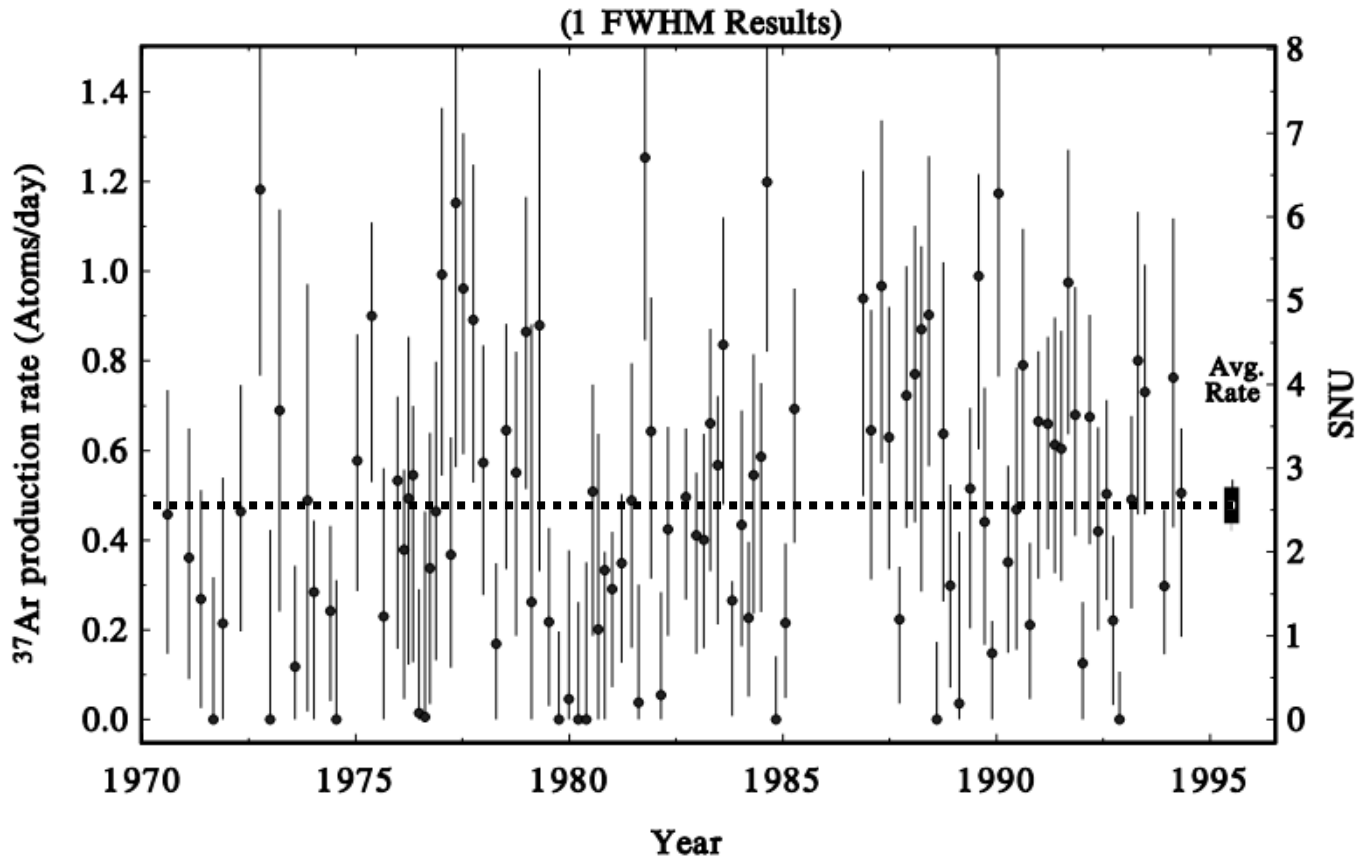
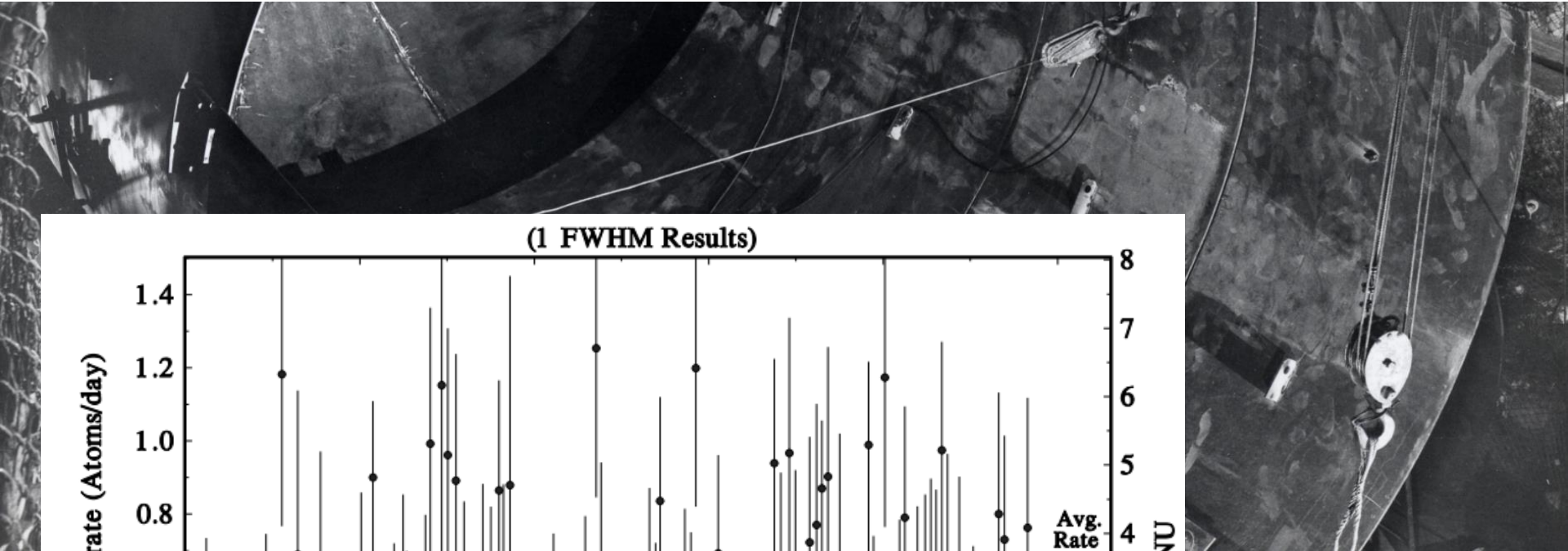
Solar neutrino telescope



814 keV threshold
615 tons C_2Cl_4

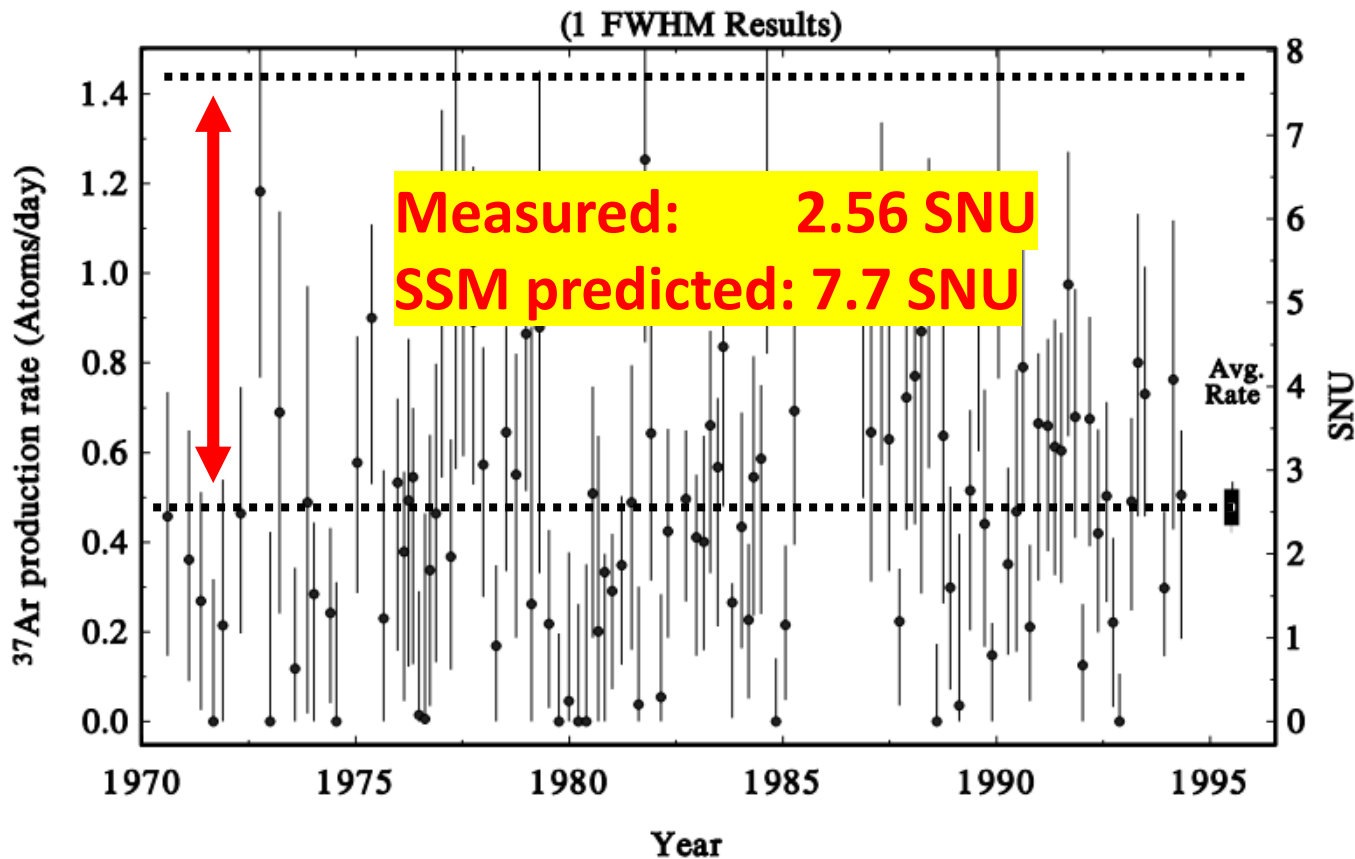
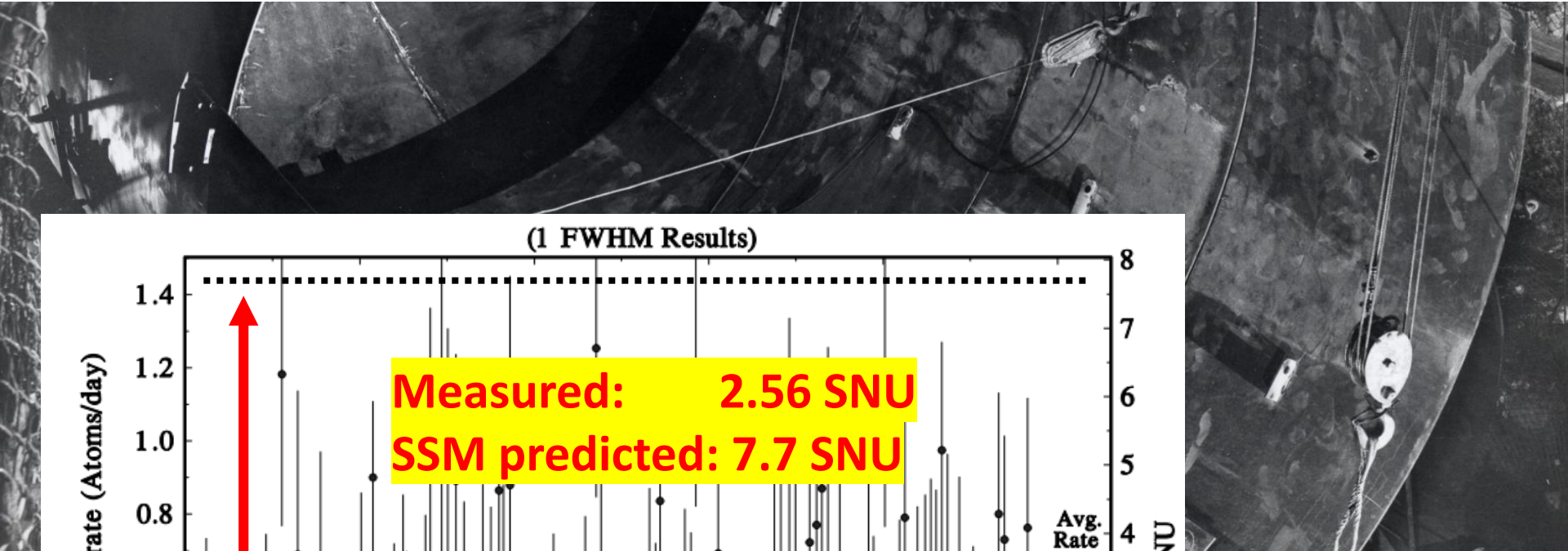


Solar neutrino telescope



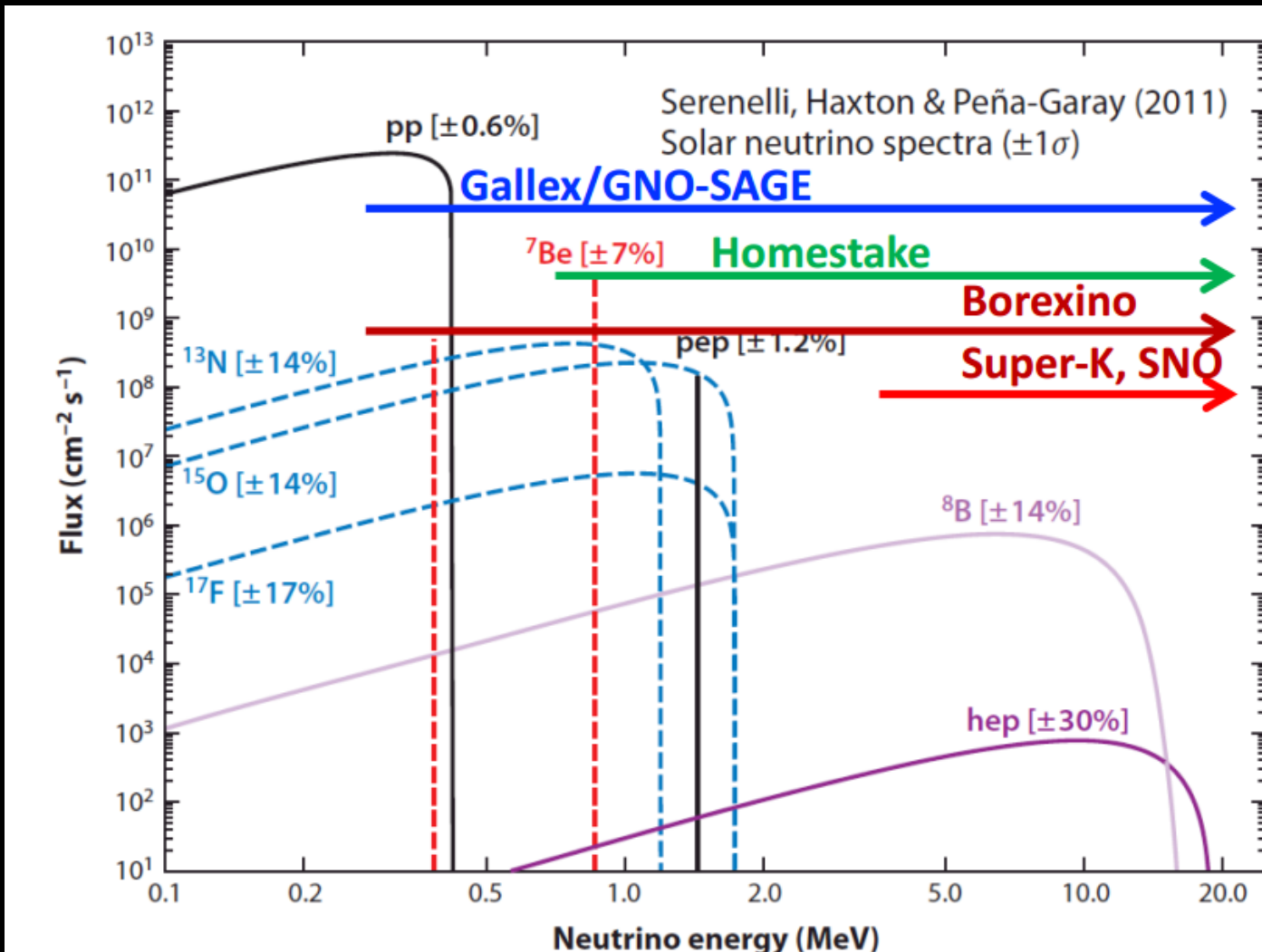
Nobel prize in physics, 2002

Solar neutrino telescope

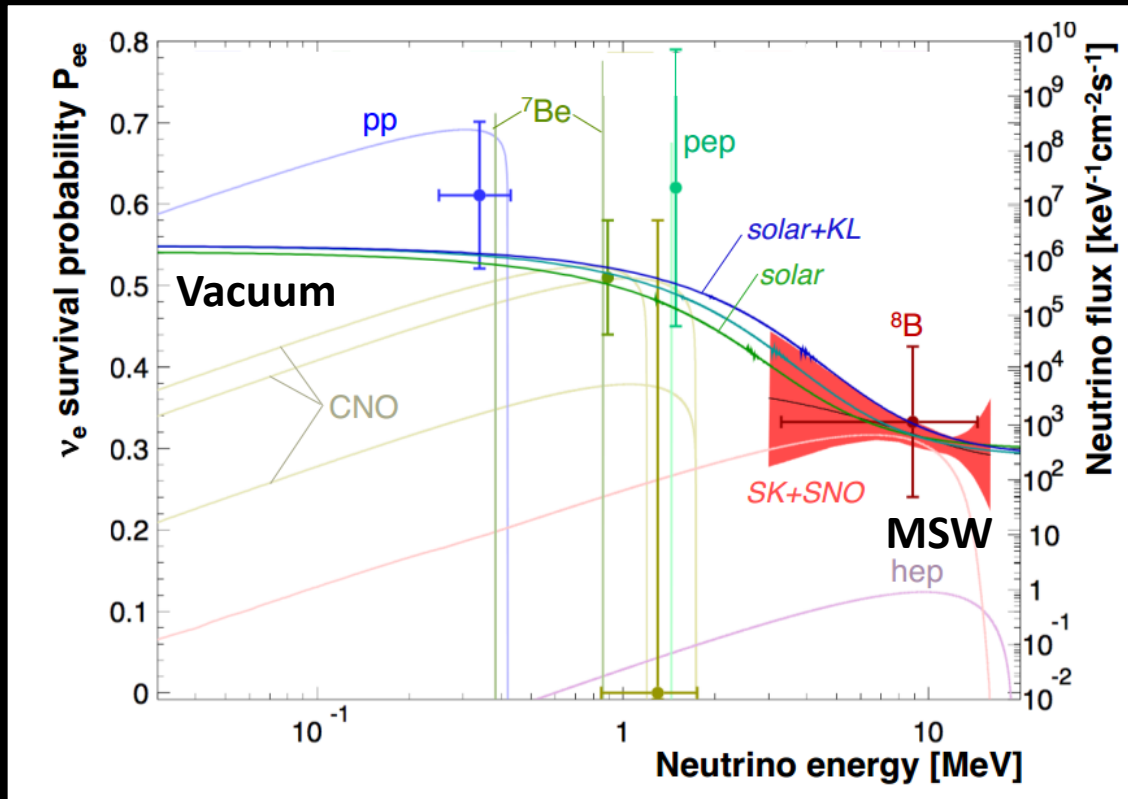


Nobel prize in physics, 2002

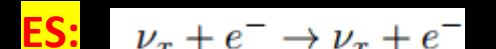
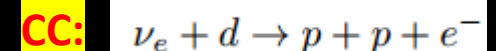
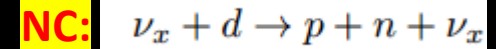
Solar neutrino experiments



Solar neutrino oscillation



SNO experiment:



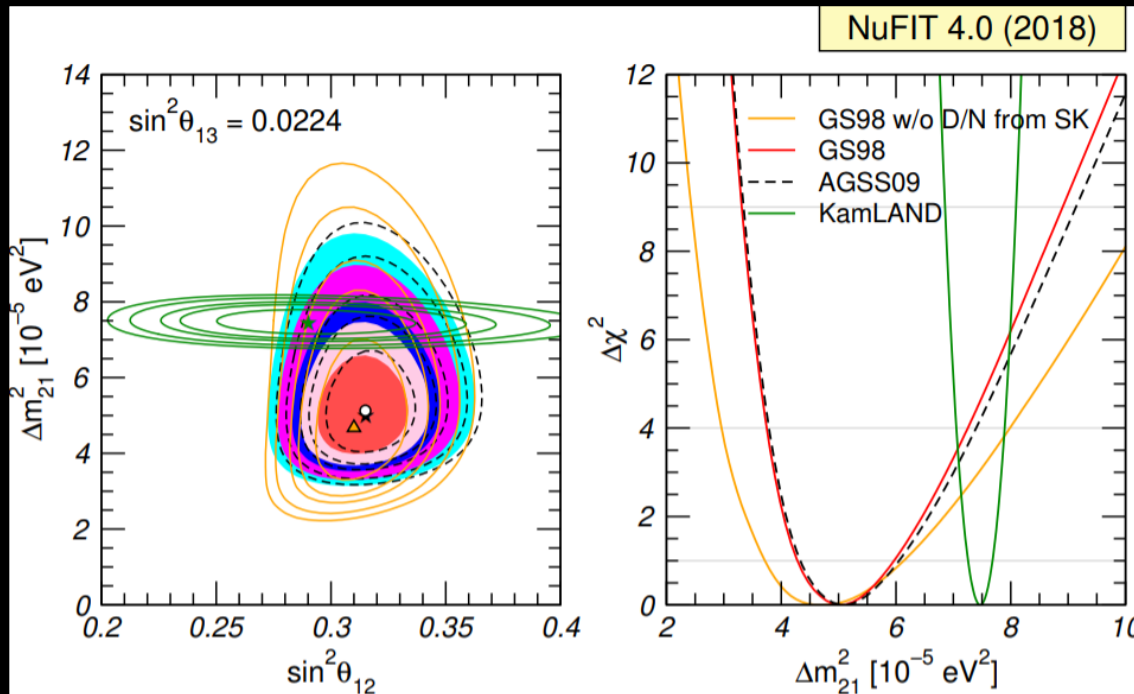
Nobel prize in physics, 2015

$$\sin 2\theta_{12}^m = \frac{\sin 2\theta_{12}}{\sqrt{(V_{CC}E/\Delta m_{21}^2 - \cos 2\theta_{12})^2 + \sin^2 2\theta_{12}}}$$

$$(\Delta m_{21}^2)^m = (m_2^2)^m - (m_1^2)^m = \Delta m_{21}^2 \cdot \sqrt{(V_{CC}E/\Delta m_{21}^2 - \cos 2\theta_{12})^2 + \sin^2 2\theta_{12}}$$

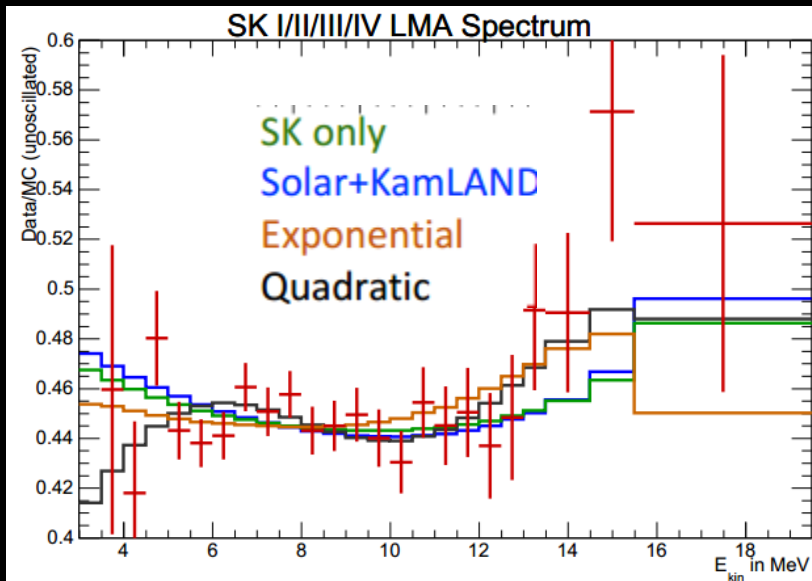
Open questions

- Observation of CNO neutrino \rightarrow Jinping
- 2σ tension of Δm^2_{21} between solar and reactor exp.
 \rightarrow A simultaneous measurement at JUNO

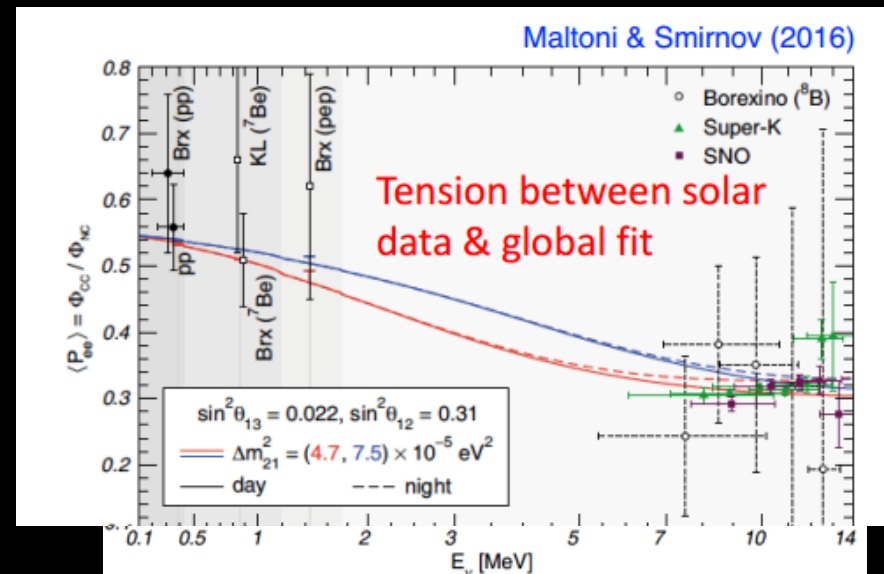


Vacuum-MSW transition

- The predicted “upturn” is not observed yet
 - Lowest detection threshold 3.2 MeV at Borexino
- Can JUNO further lower the threshold?

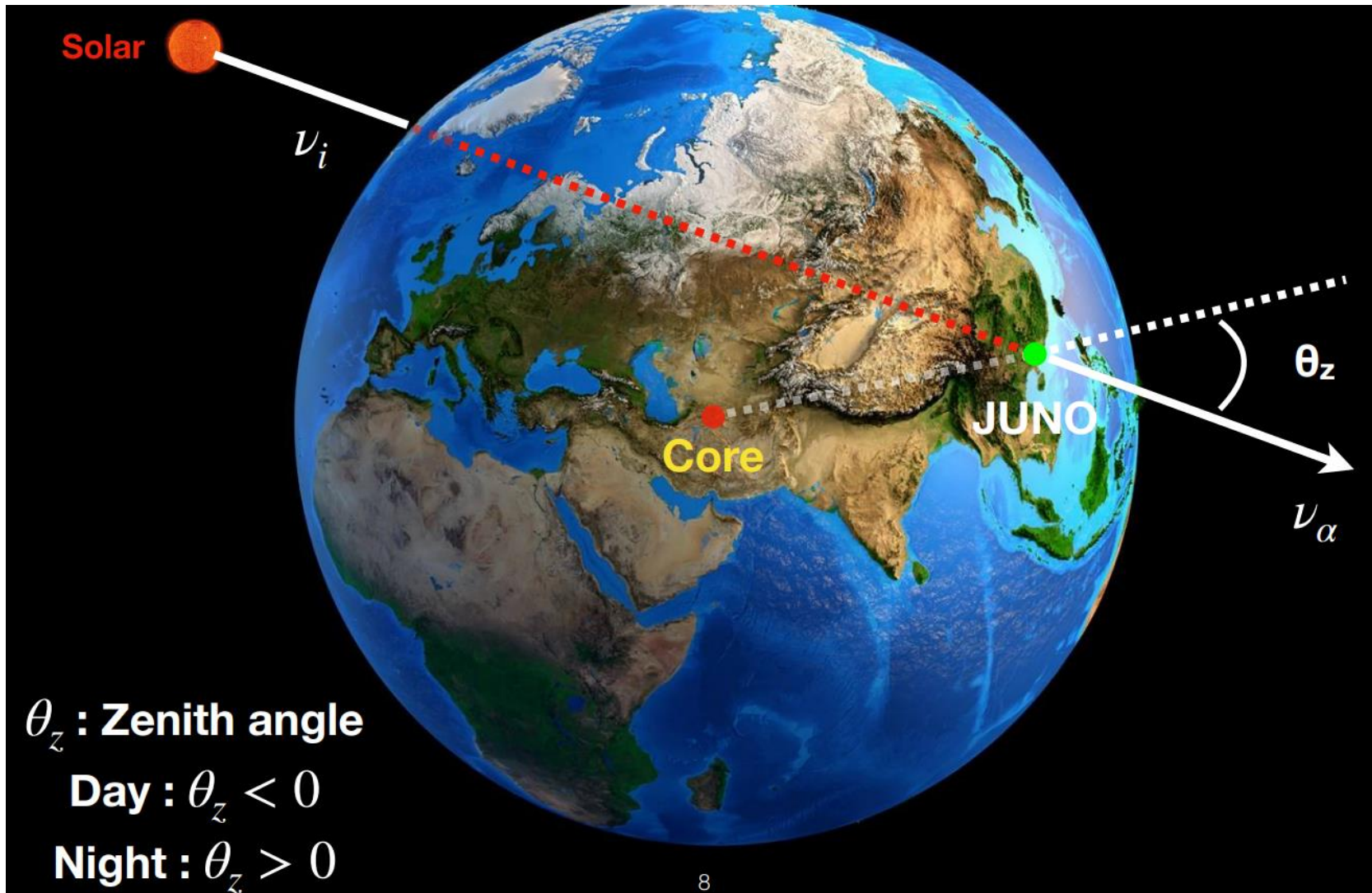


PRD 94, 052010 (2016)



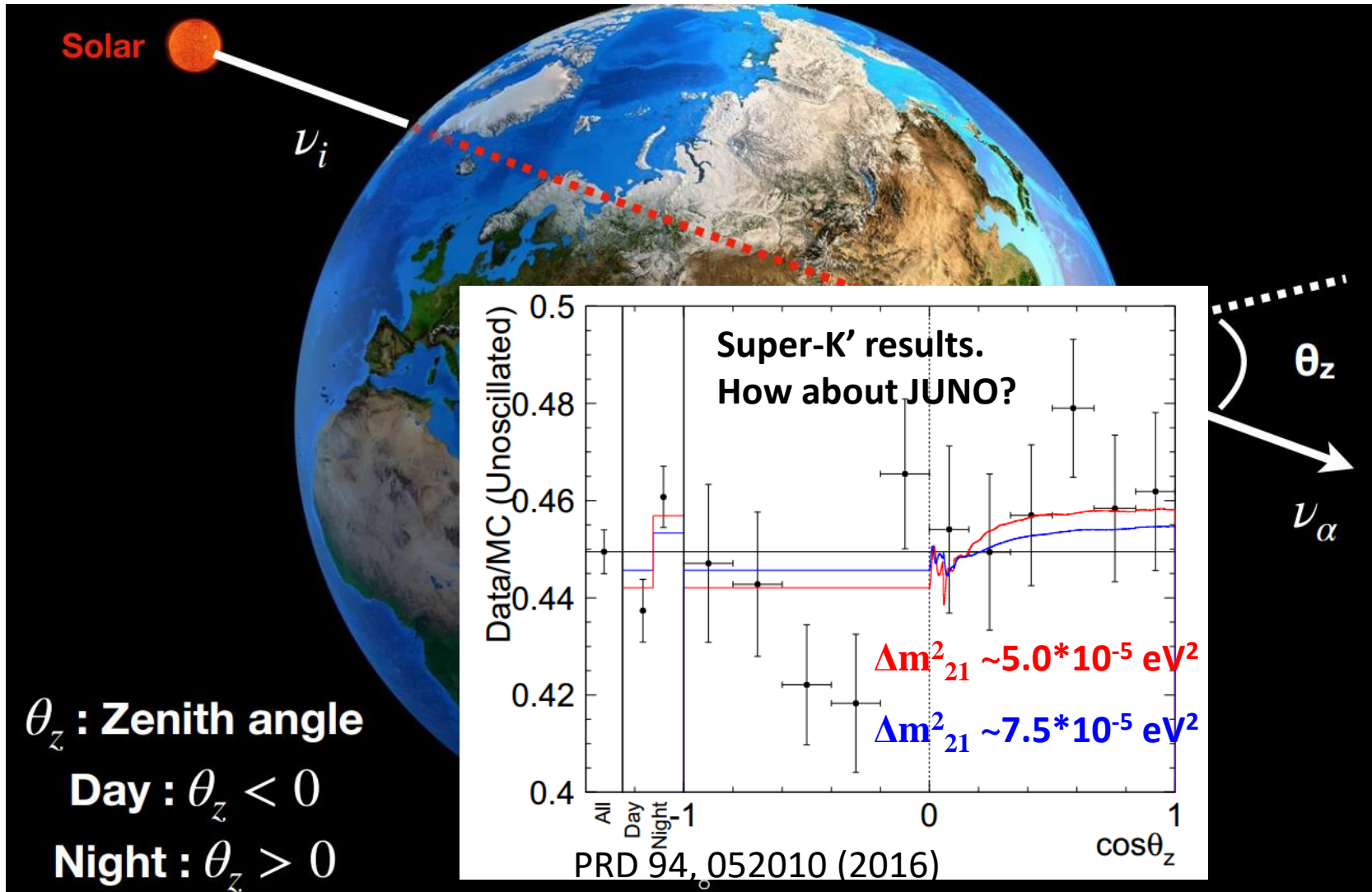
Maltoni & Smirnov (2016)

Terrestrial matter effects



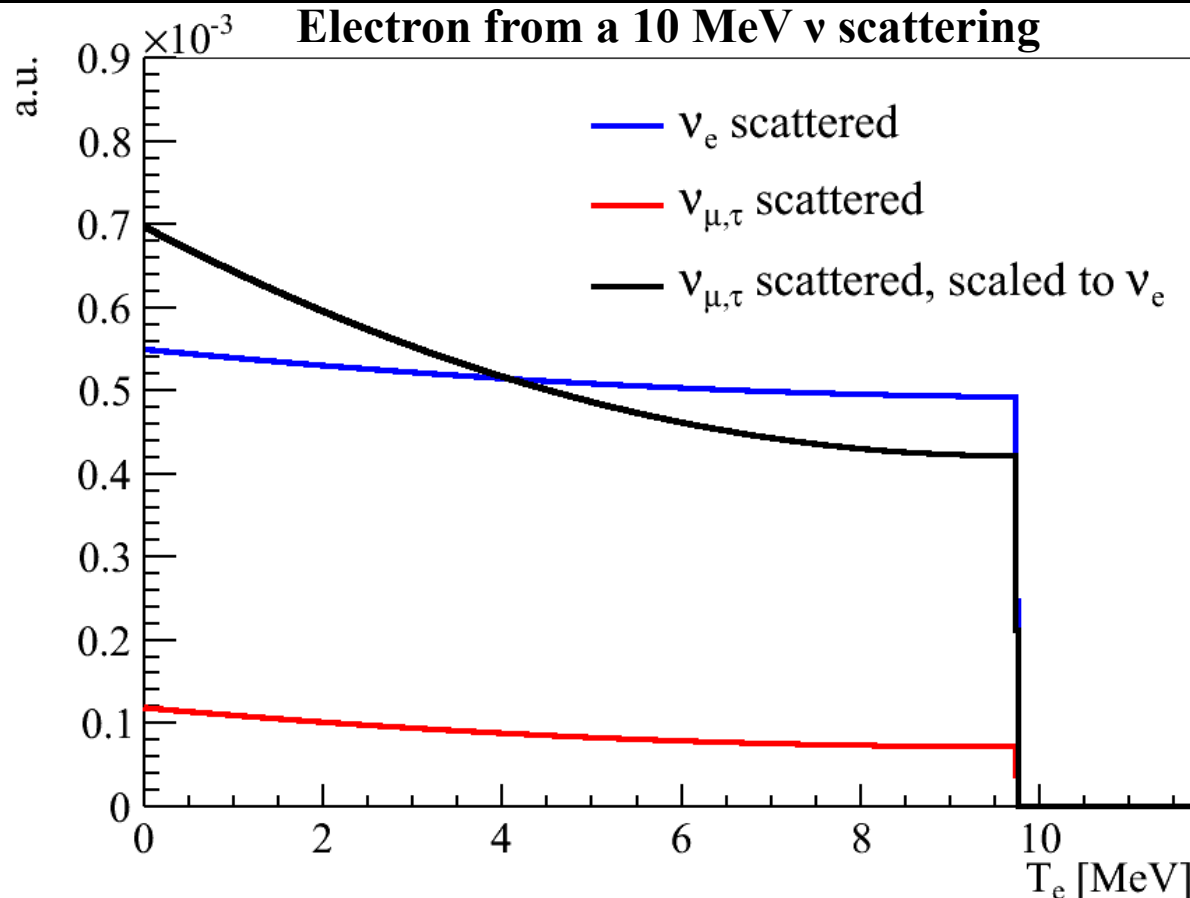
Plot from Baobiao

Terrestrial matter effects

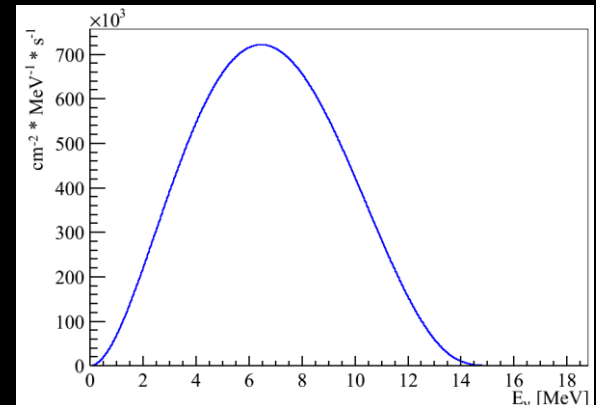


Solar ν detection at JUNO

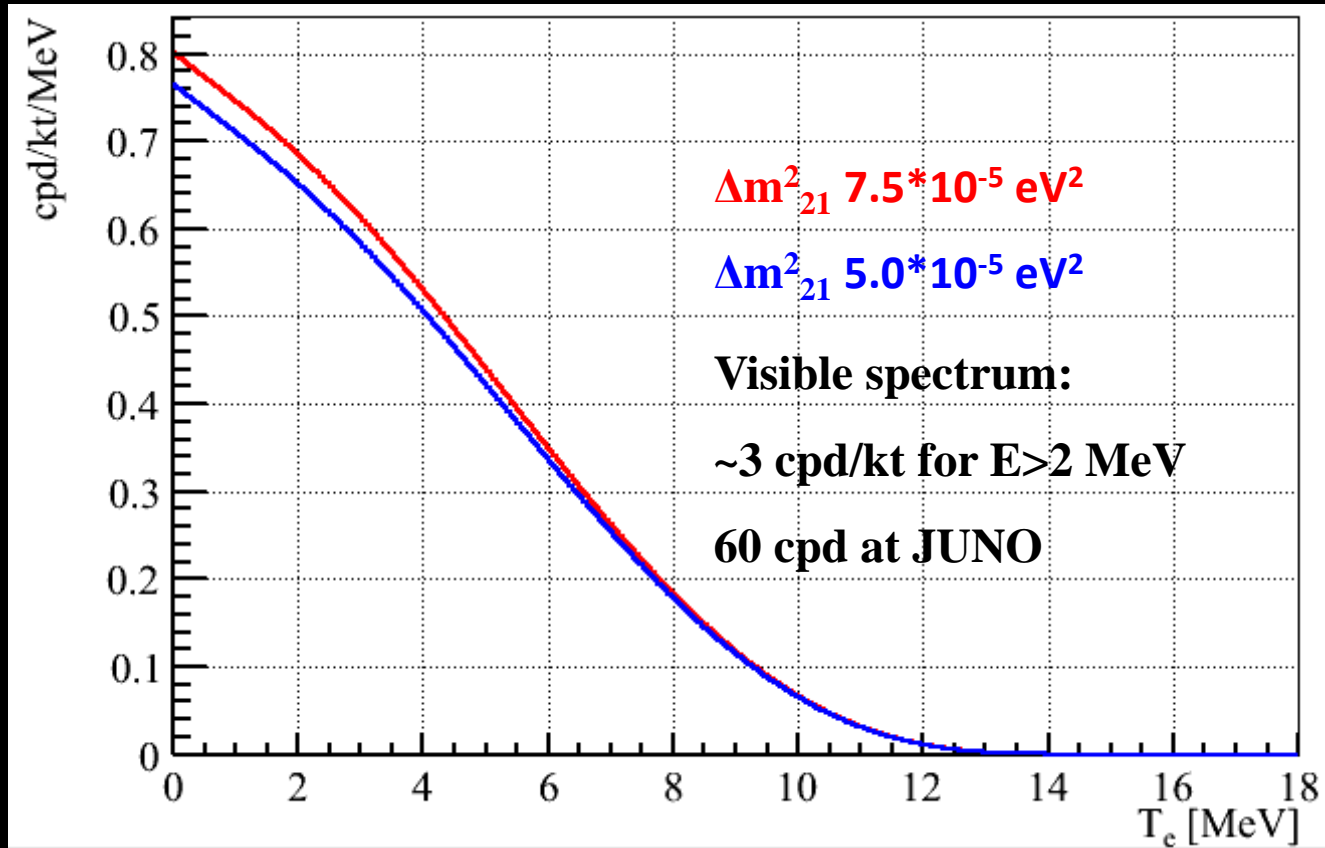
Primary detection channel



^8B neutrino spectrum



Solar ν detection at JUNO

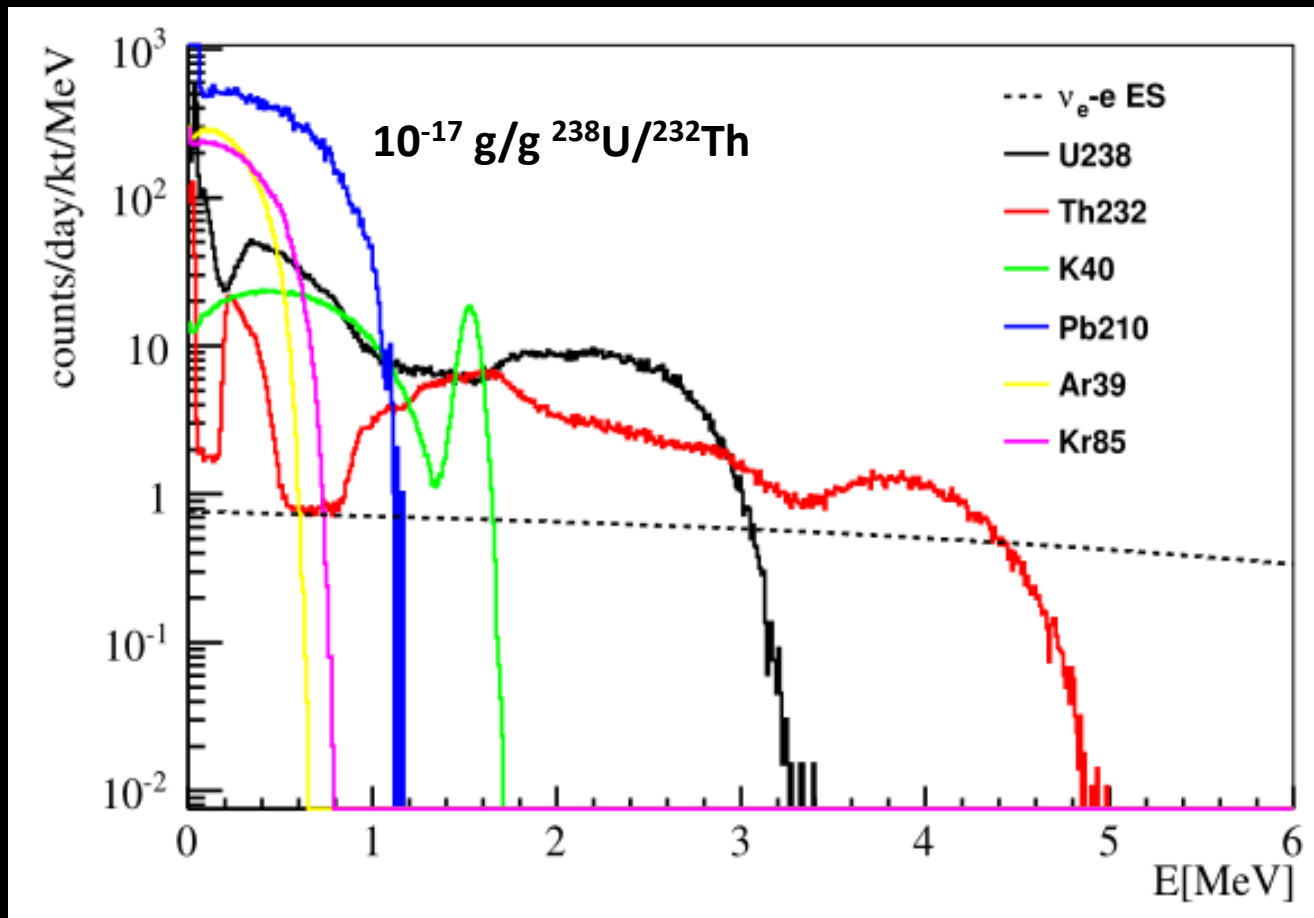


- Scattered electron: **isolated signal**

Natural radioactivity and cosmogenic backgrounds

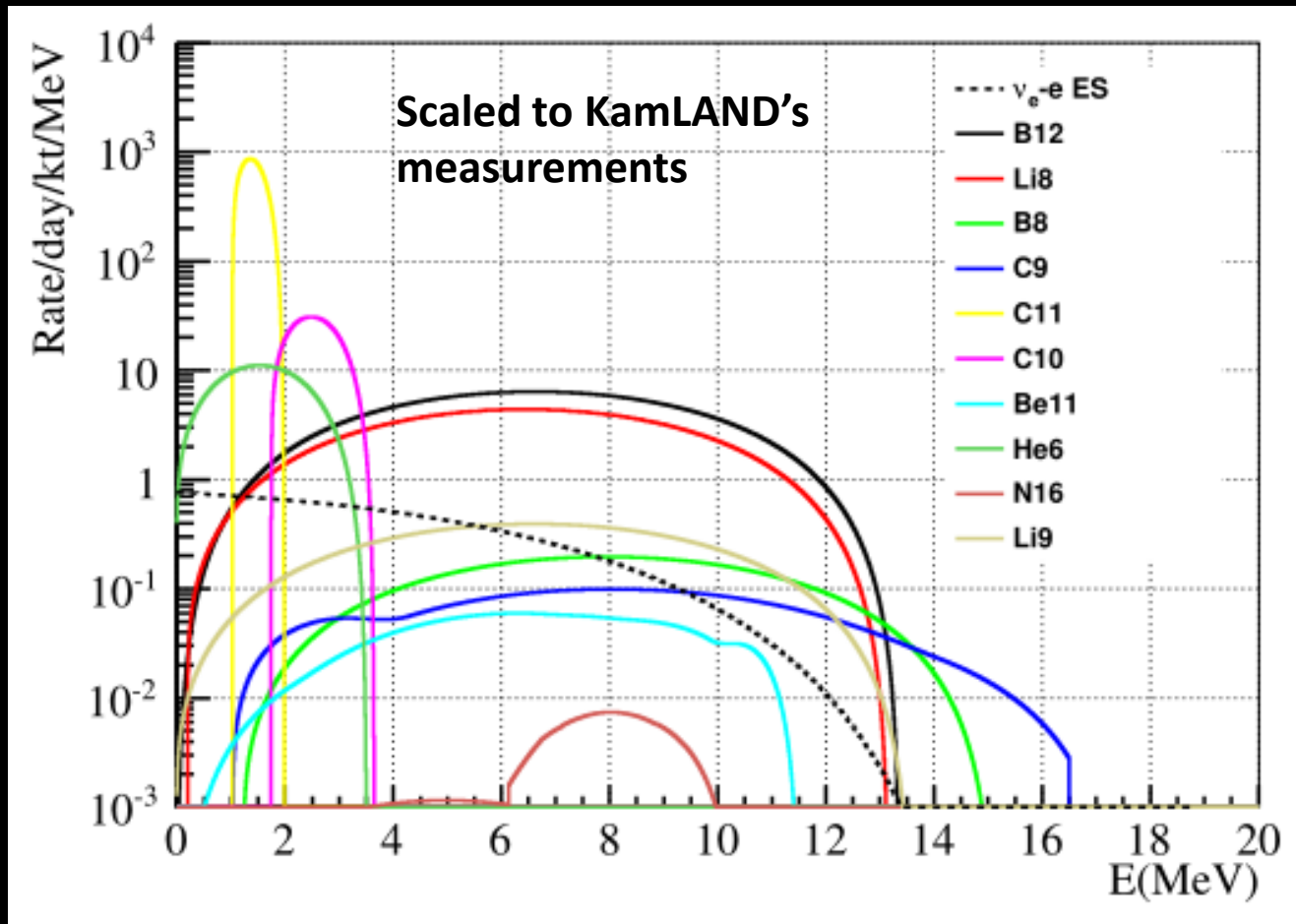
Solar ν detection at JUNO

Natural radioactivity



Solar ν detection at JUNO

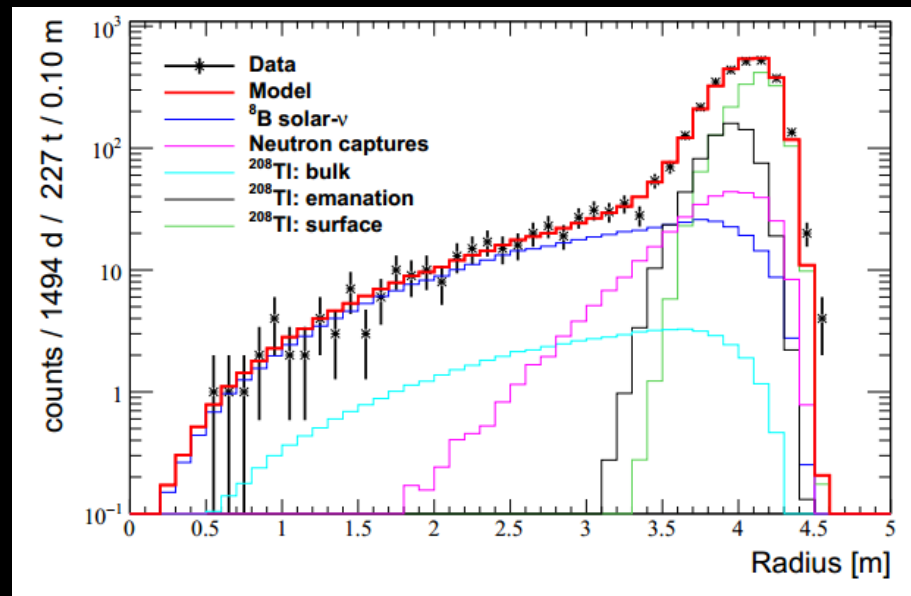
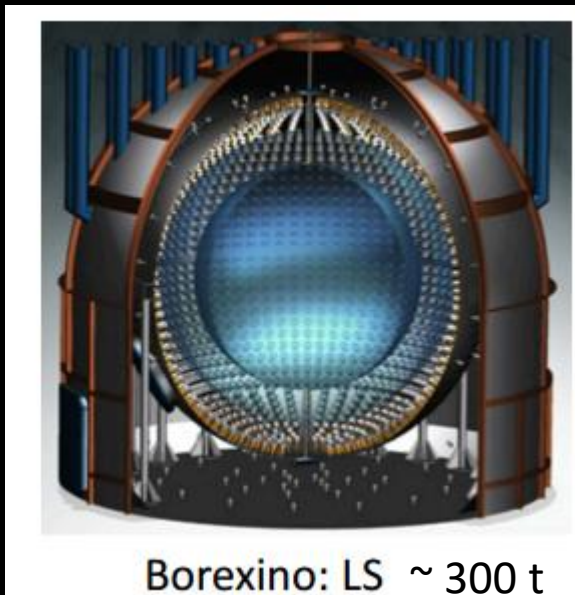
Cosmogenic isotopes



External background

Larger detector \rightarrow better self shielding

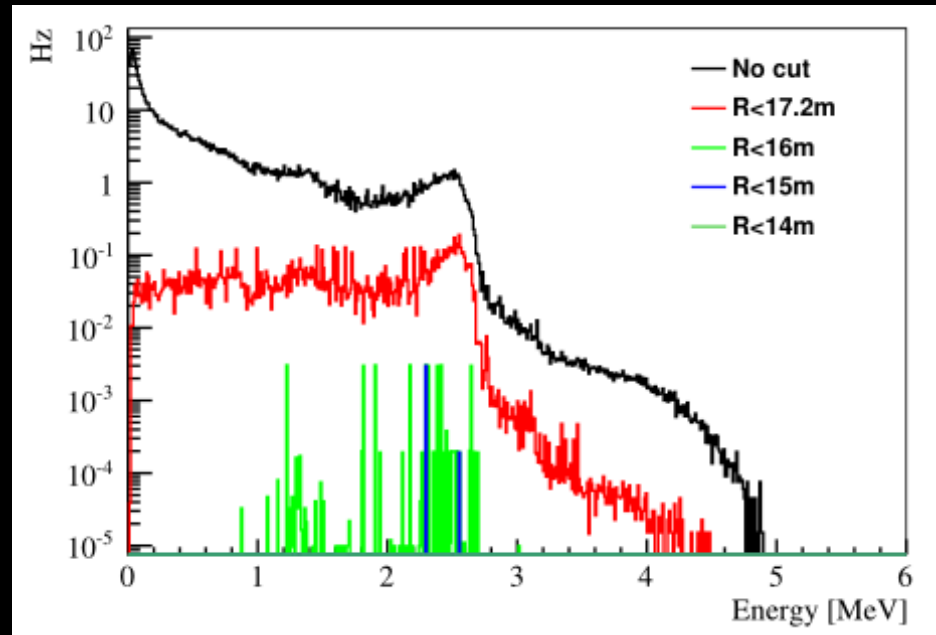
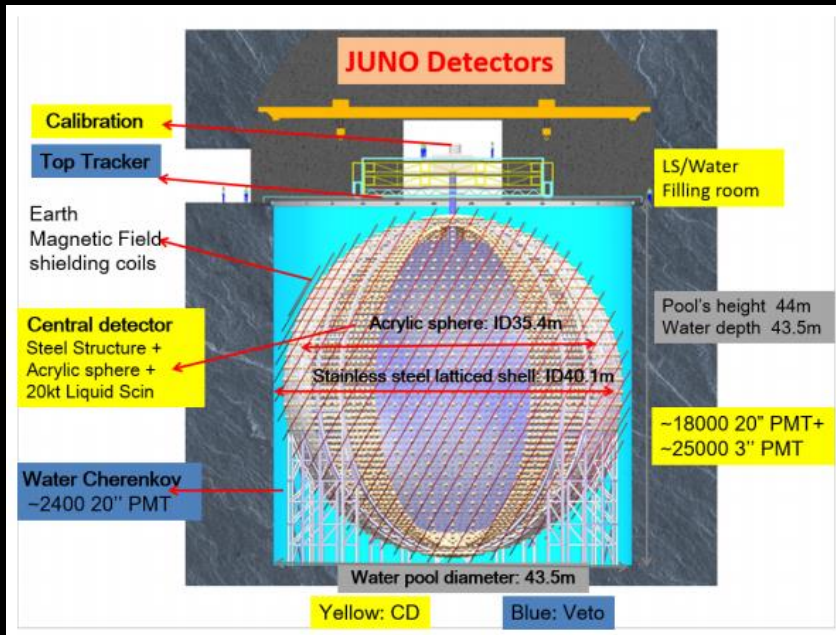
Borexino 3.2 MeV detection threshold



External background

Larger detector \rightarrow better self shielding

JUNO: 10 kt FV without external background



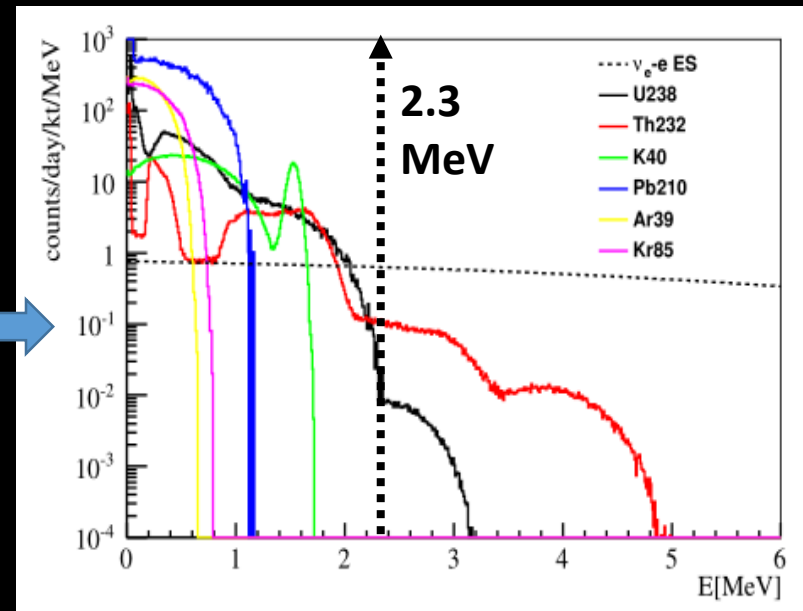
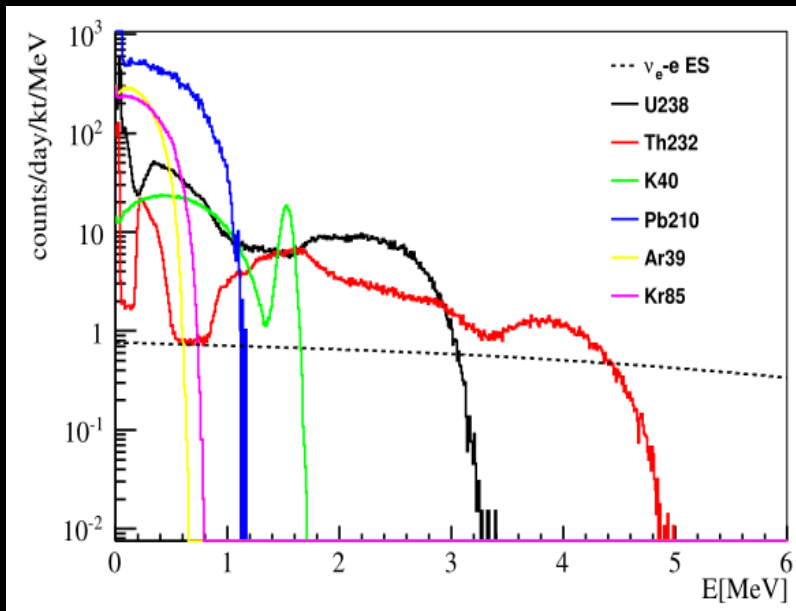
Internal background

Clean LS: U/Th 10^{-17} g/g

- Cascade decays to further reject Bi-Po-Pb/Bi-Tl-Pb
- Can reach same threshold with 10^{-16} g/g U/Th

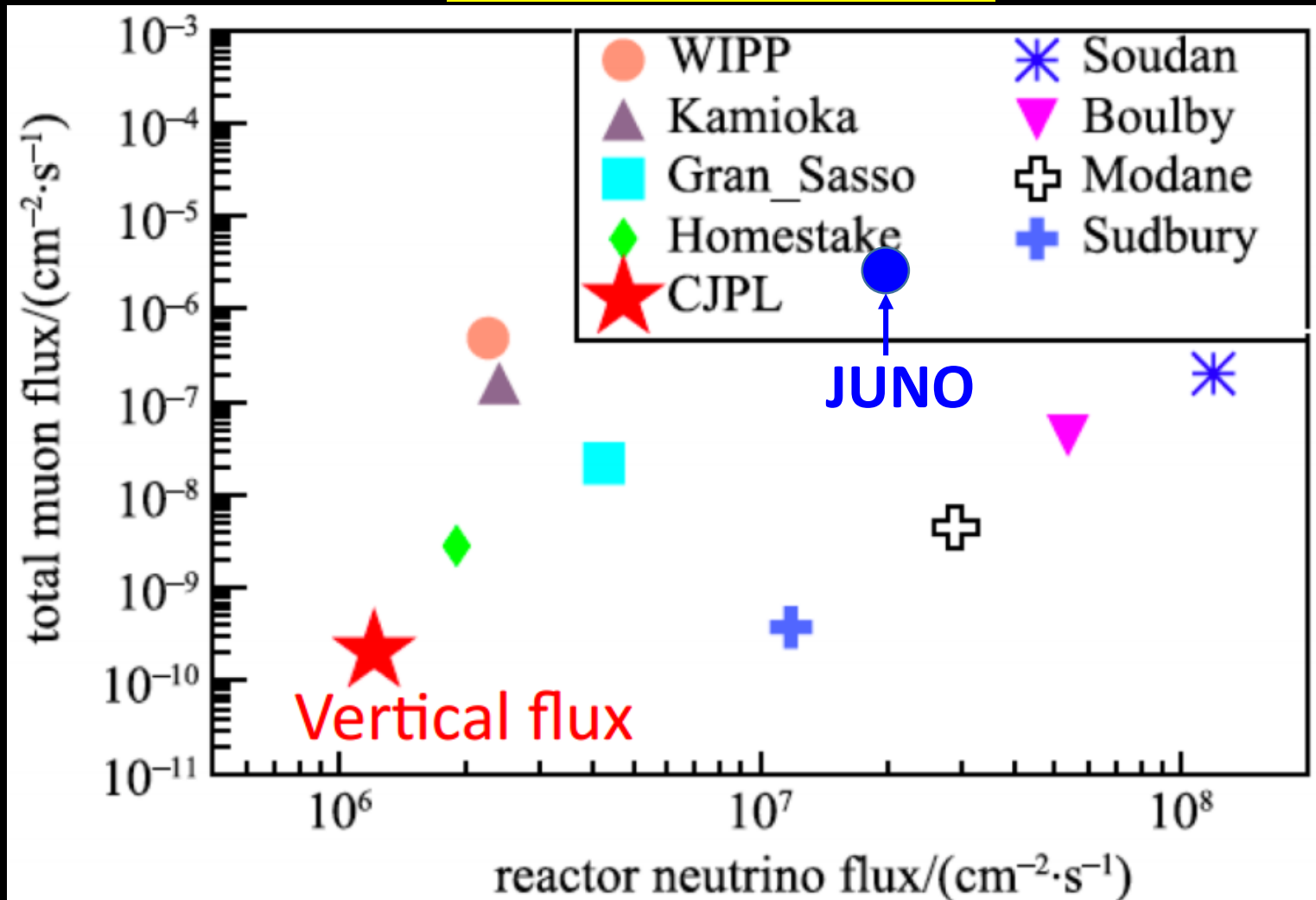
JUNO: first 2.3 MeV detection threshold!

- Borexino: 3.2 MeV, SK/SNO: 3.5 MeV



Cosmogenic isotopes

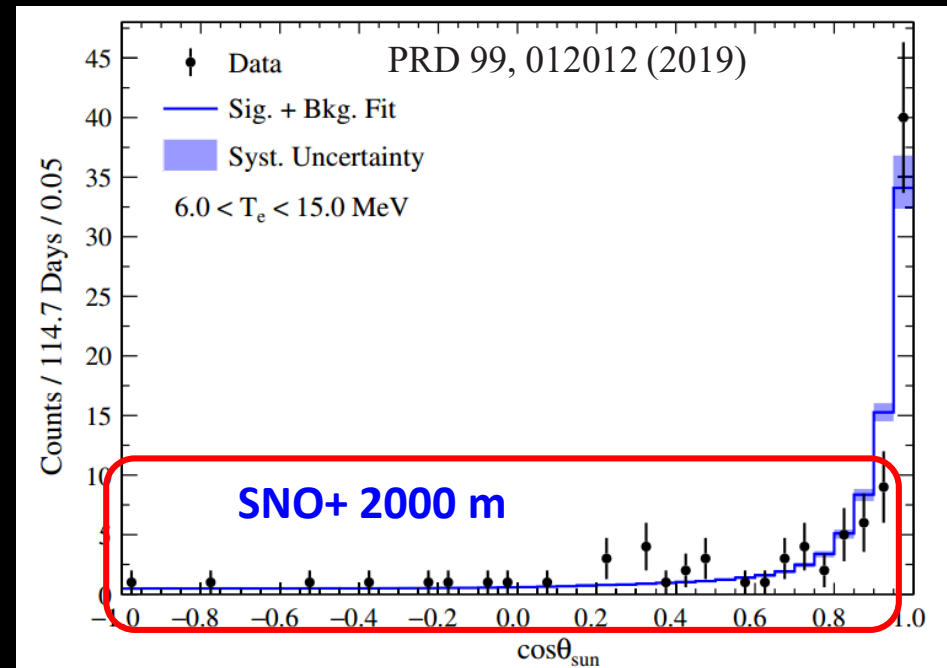
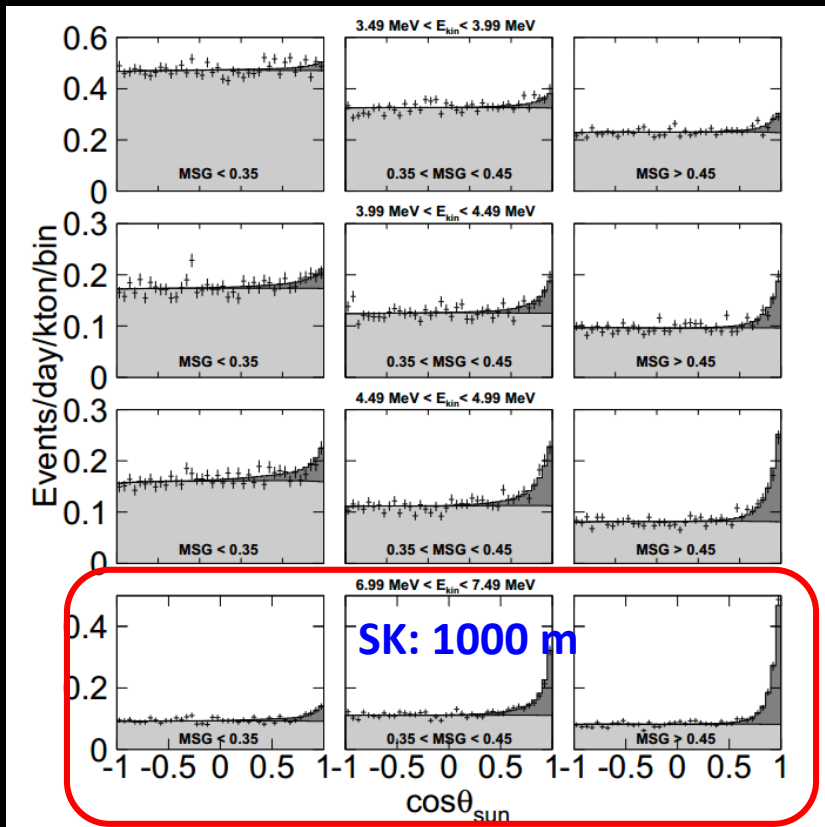
Deeper underground



Cosmogenic isotopes

Super-K : use direction to estimate residual bkg

JUNO 700 m : no direction, then?



Cosmogenic isotopes

Common veto a cylinder volume along muon track

Super-K very low detection efficiency to n-H

JUNO veto isotopes by accompanied neutrons

G4	Yield(day)	Neutron accompany efficiency(%)
B12	916.8	77.0%
Li8	627.9	83.3%
C10	707.2	96.8%
He6	455.7	86.4%
B8	30.1	98.6%
Li9	58.8	91.7%
Be11	8.0	86.2%
N16	0.48	88.8%

Data

Measuring @ Daya Bay

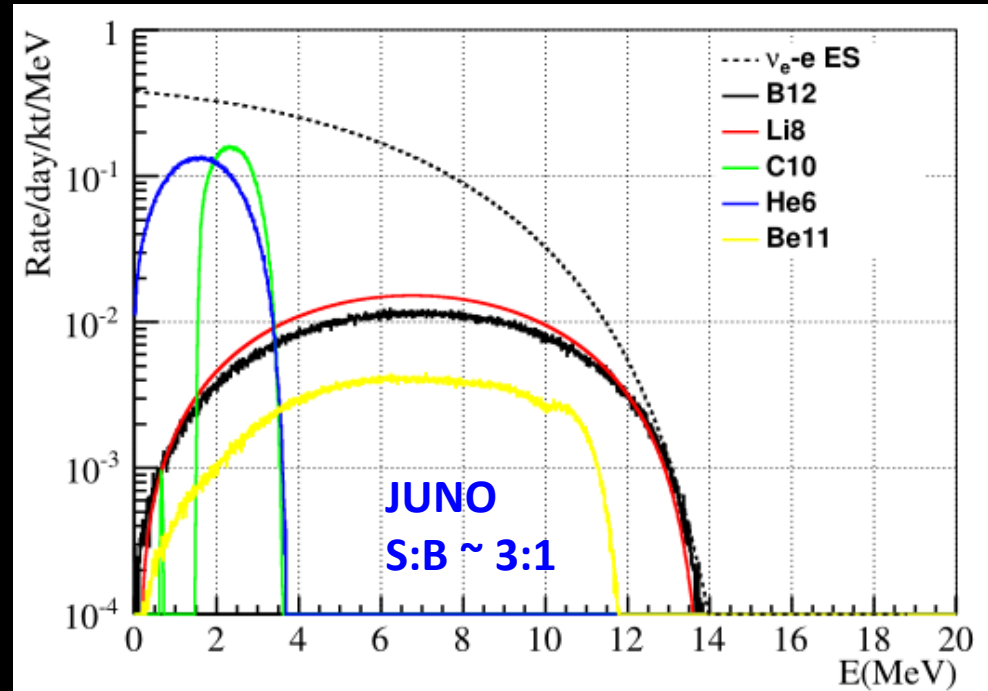
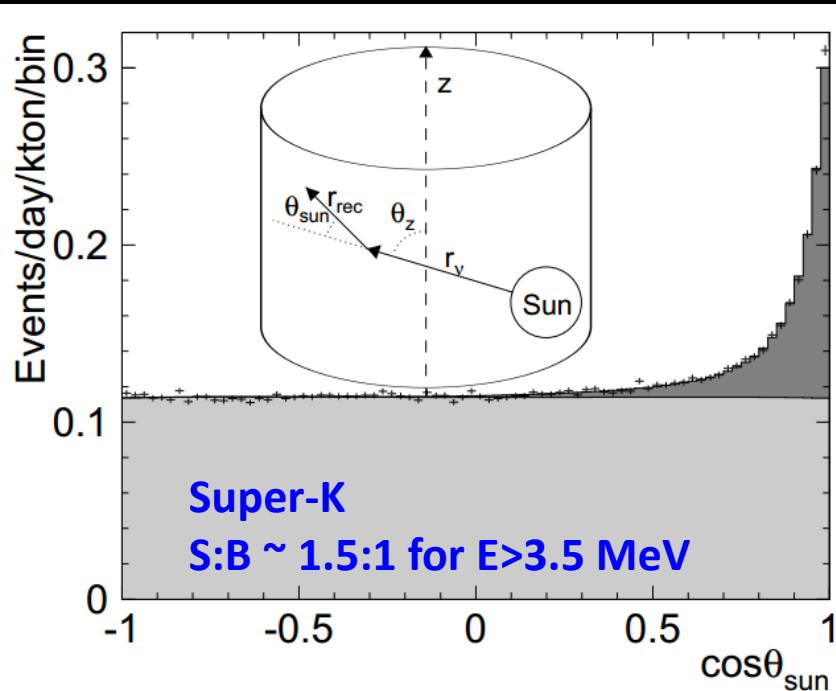
~96% @ Borexino

> 90% @ Daya Bay

Provided by Haoqi

Cosmogenic isotopes

Experiment	Direction	Neutron	S:B	Uncertainty
SK 3.5-19 MeV	Yes	No	1 : 1.5	Statistics + systematics, 1%
JUNO 2.3-20 MeV	No	Yes	3 : 1	Systematics, 1~2%



$$S:B \sim 3:1$$

External background

- Self shielding

Internal background

- Clean LS, cascade decays

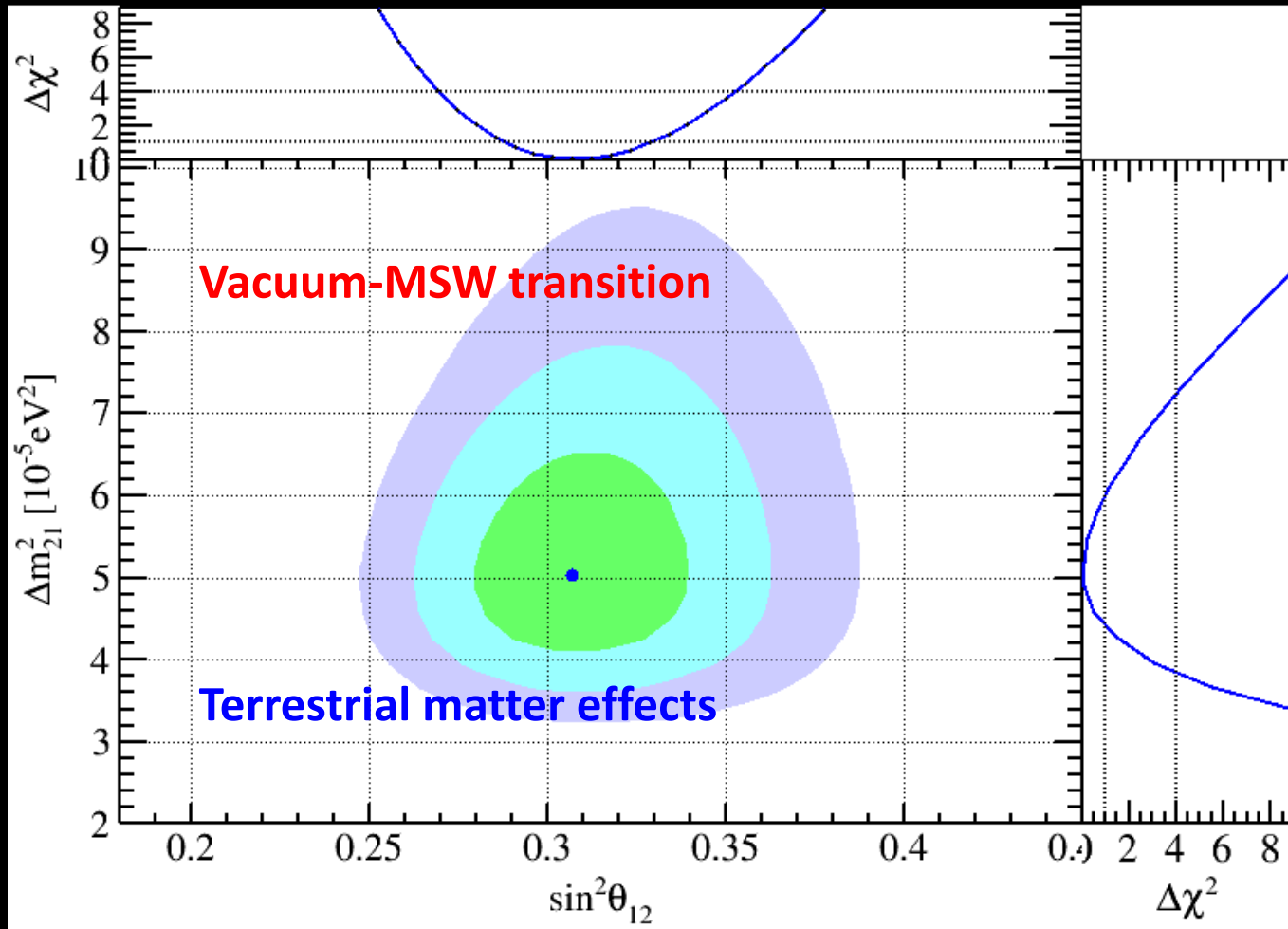
Cosmogenic isotopes

- Vetoed along muon track and around cosmogenic neutrons

unit: cpd/kt	¹² B	⁸ Li	¹⁰ C	⁶ He	¹¹ Be	²³⁸ U	²³² Th	$\bar{\nu}$ -e ES	Total bkg	B8 signal	
										dm21=7.5	dm21=5
(2,3,3)MeV	0.004	0.005	0.095	0.051	0.001	0.002	0.030	0.028	0.22	0.23	0.22
(3,5)MeV	0.017	0.022	0.018	0.010	0.006	0	0.012	0.019	0.10	0.53	0.51
(5,16)MeV	0.066	0.083	0	0	0.022	0	0	0.001	0.17	0.62	0.60
sys. err	1%	2~3%	5~10%	2~3%	5~10%	1%	1%	2%			

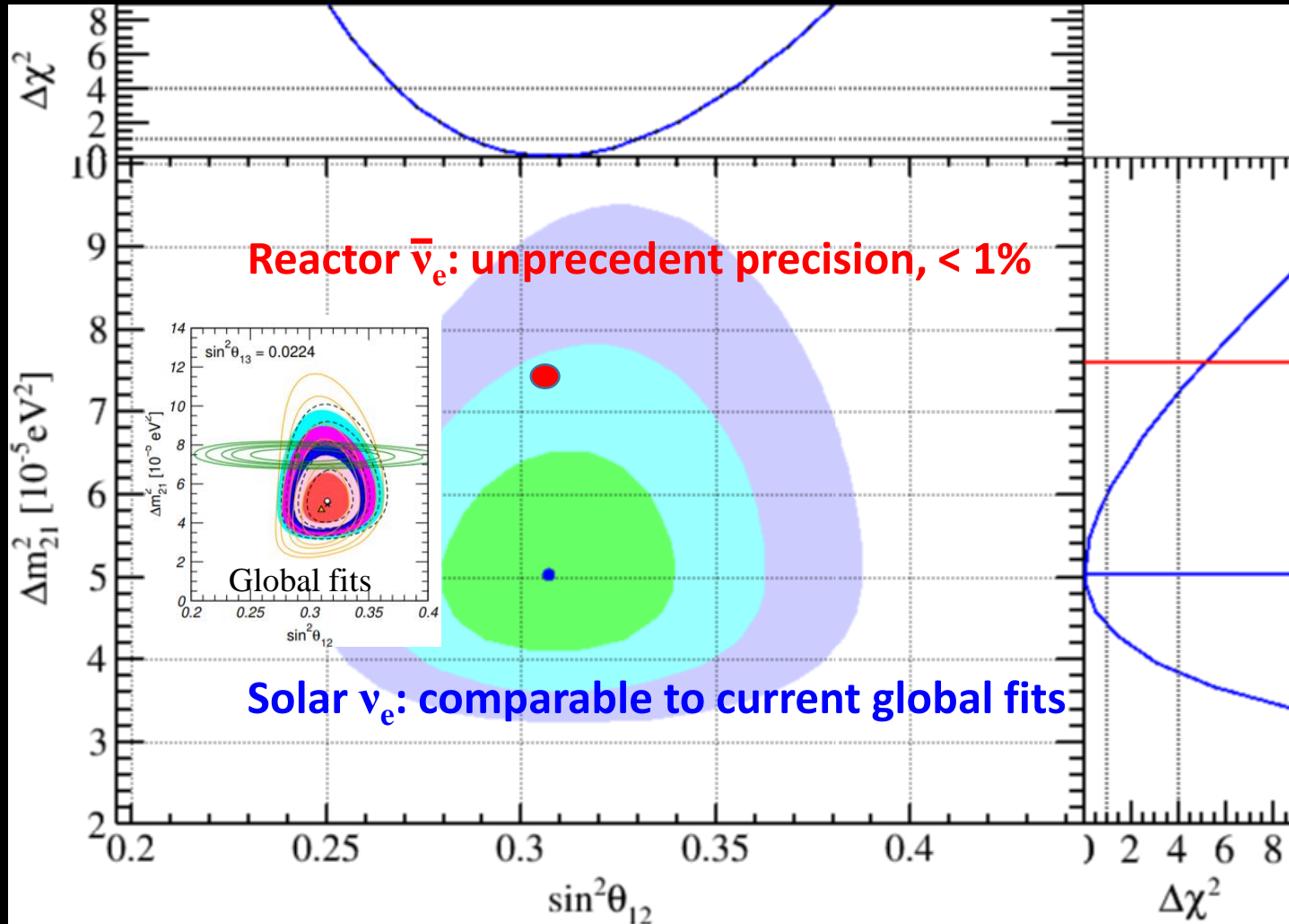
Solar oscillation parameters

JUNO 10 years solar assume true Δm_{21}^2 $5 \cdot 10^{-5} \text{ eV}^2$



Solar oscillation parameters

JUNO 10 years solar + 10 years reactor

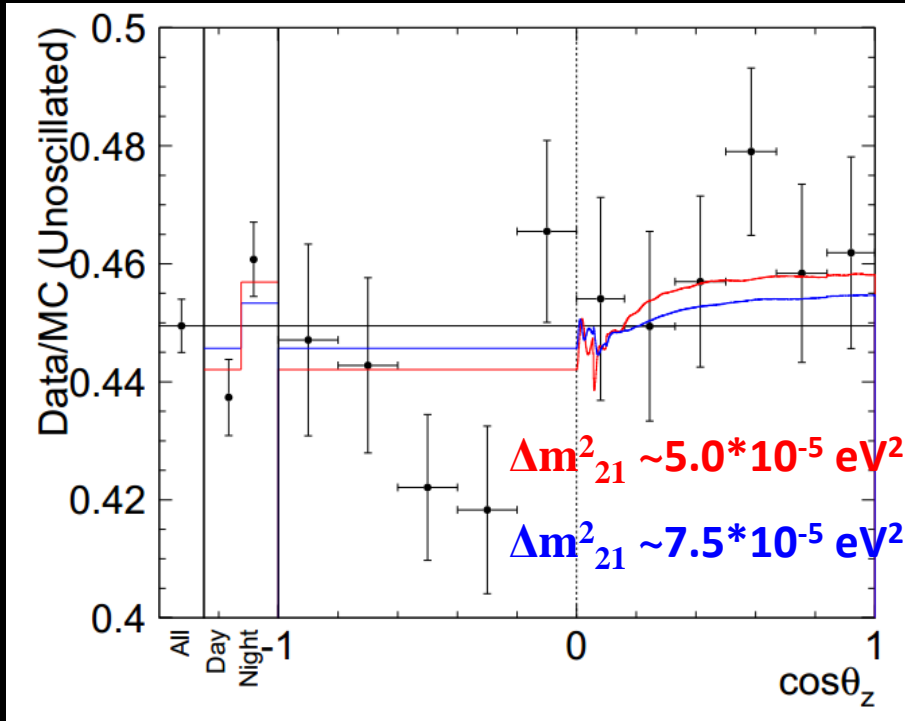


JUNO solar summary

- **Simultaneous reactor $\bar{\nu}_e$ and solar ν_e measurement**
- **With 10 years data taking, $10^{-17(-16)}$ g/g U/Th in LS:**
 - **The first** 2.3 MeV detection threshold: new physics probes
 - **Terrestrial MSW** comparable (even better) to SK 20 years
 - **Δm^2_{21}** : comparable precision to current solar global fits
- **Other solar neutrinos are under investigation**

Backup

- **Terrestrial MSW**



SK 20 years

$$A_{\text{DN}}^{\text{fit,SK}} = (-3.3 \pm 1.0(\text{stat}) \pm 0.5(\text{syst}))\%$$

JUNO 10 years

$$-3.05 \pm 0.86(\text{stat.}) \pm 0.05(\text{sys.})$$

^7Be solar neutrino

- Spectral fit (Borexino)

