DUNE as the Next-Generation Solar Neutrino Experiment

Shirley Li

arXiv: 1808.08232

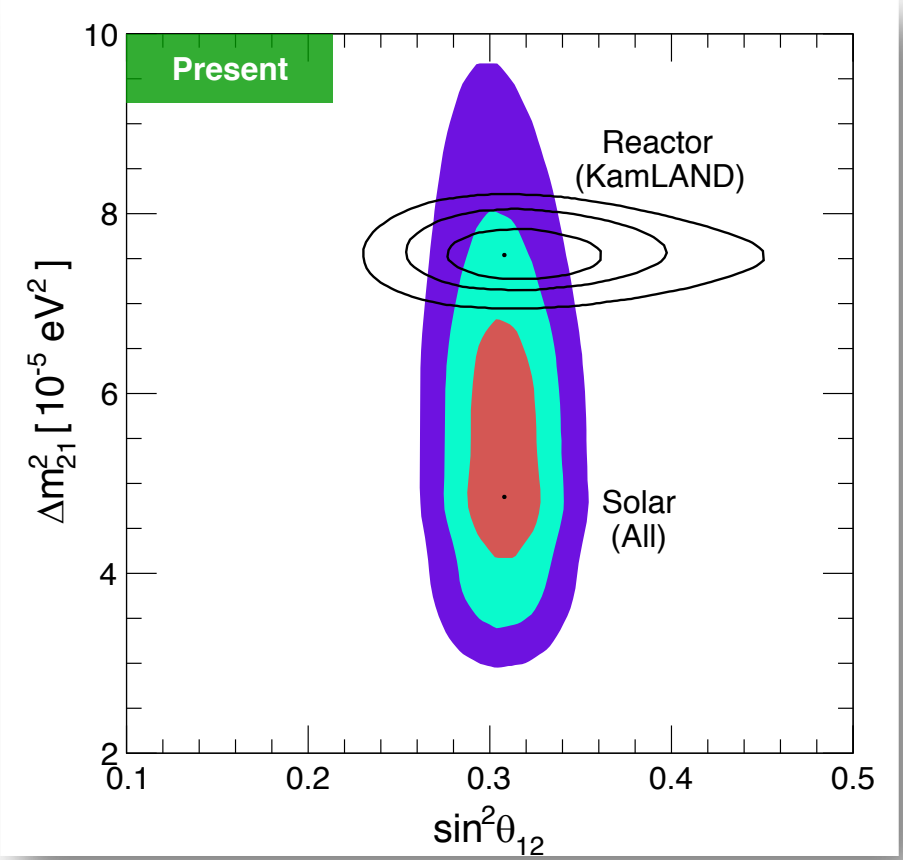
Collaborators: F. Capozzi, G. Zhu, J. Beacom

PONDD, December 2018

Outline

Data from SK 2016

DUNE comes to rescue!



What is this?

Why haven't we resolved this?

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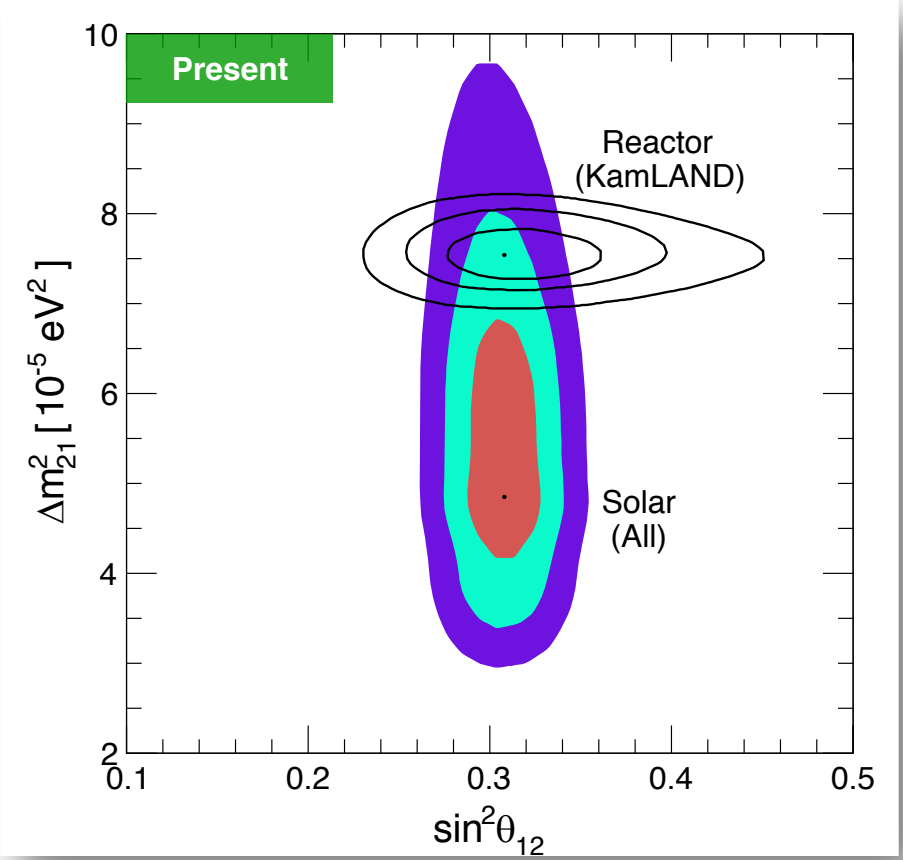

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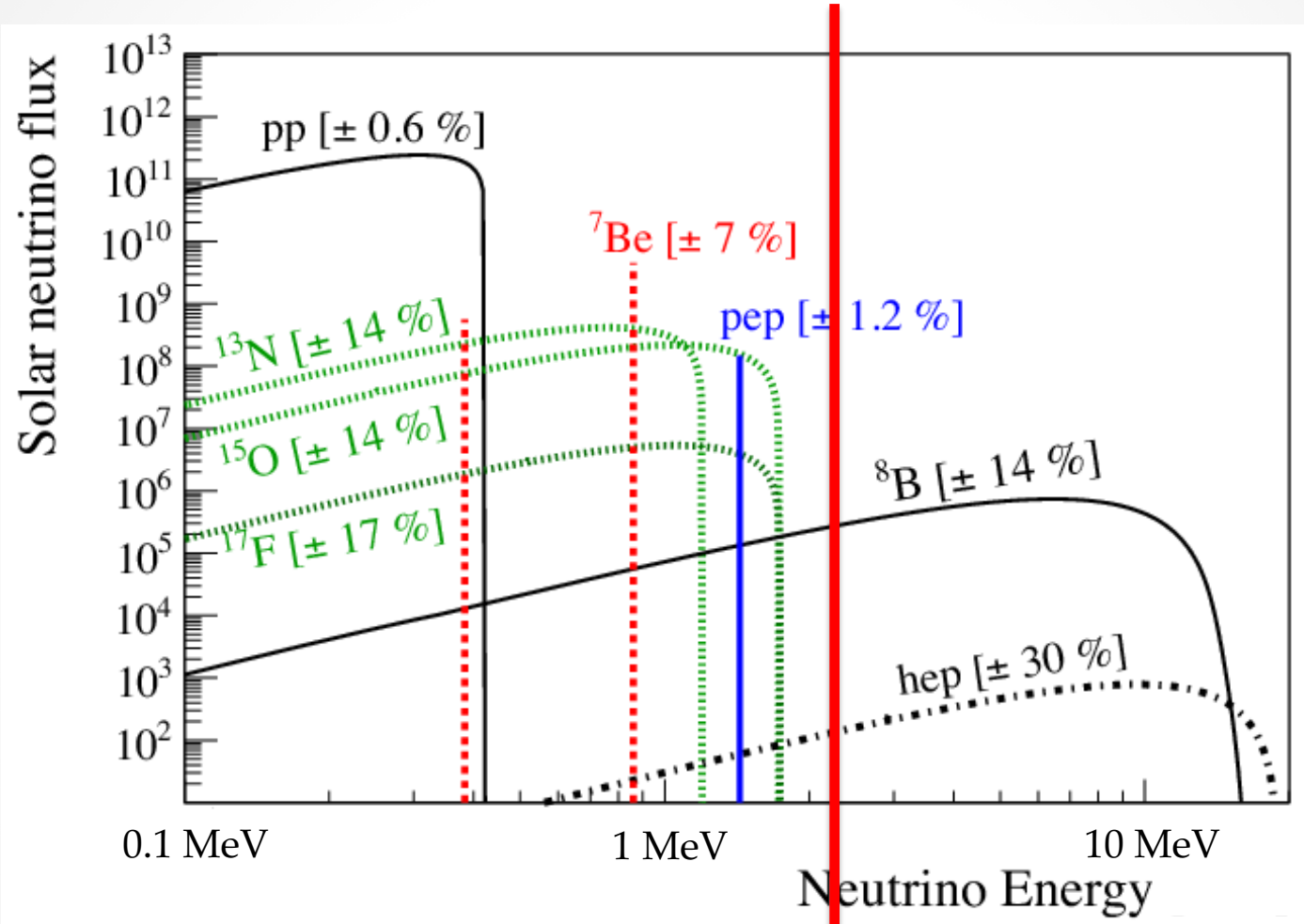
Solar neutrino spectra



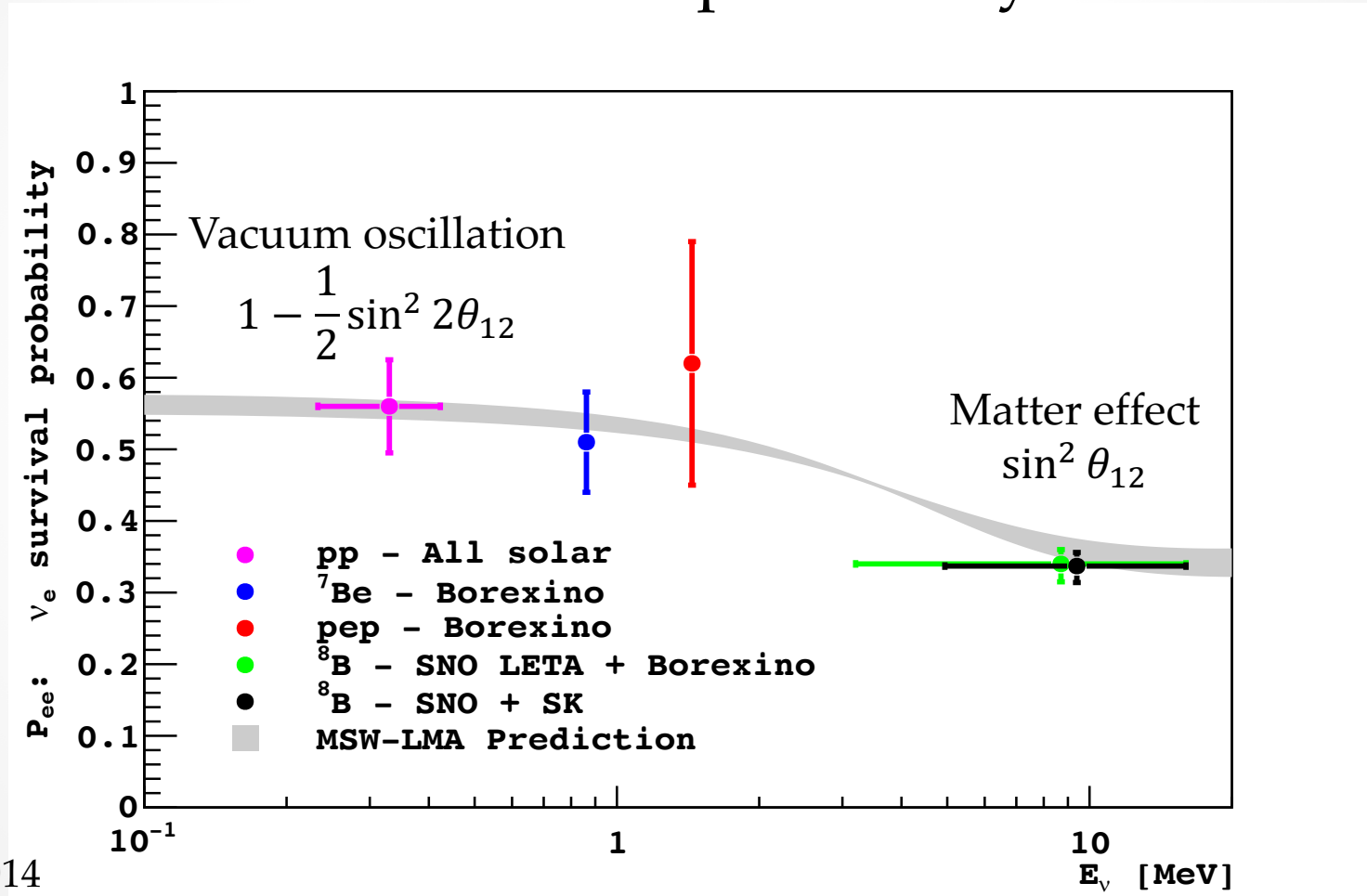
Borexino 2014

8B: used for oscillation study

hep: haven't been detected

Solar neutrino oscillation

The survival probability

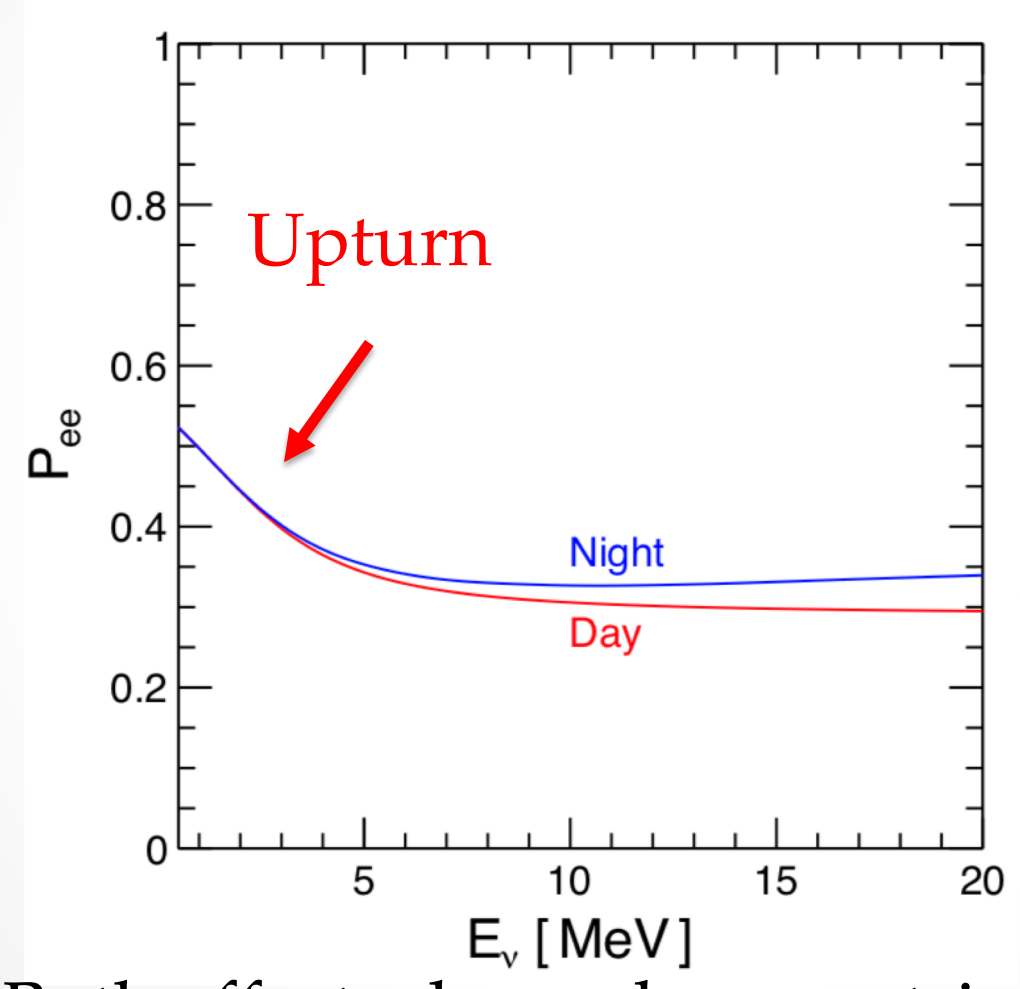


Borexino 2014

Good agreement?

Oscillation phenomena

Two matter-induced effects



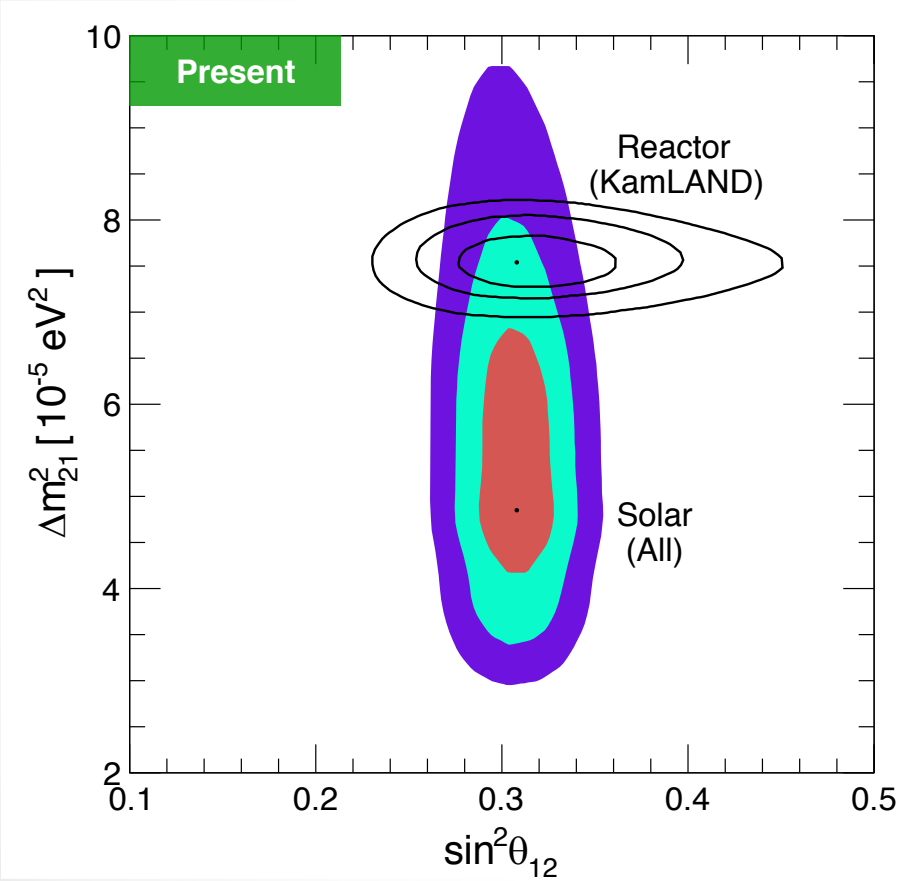
Capozzi et al, 2018

Both effects depend on neutrino energy

Current status

Data from SK 2016

Solar & reactor tension



Reactor: vacuum oscillation

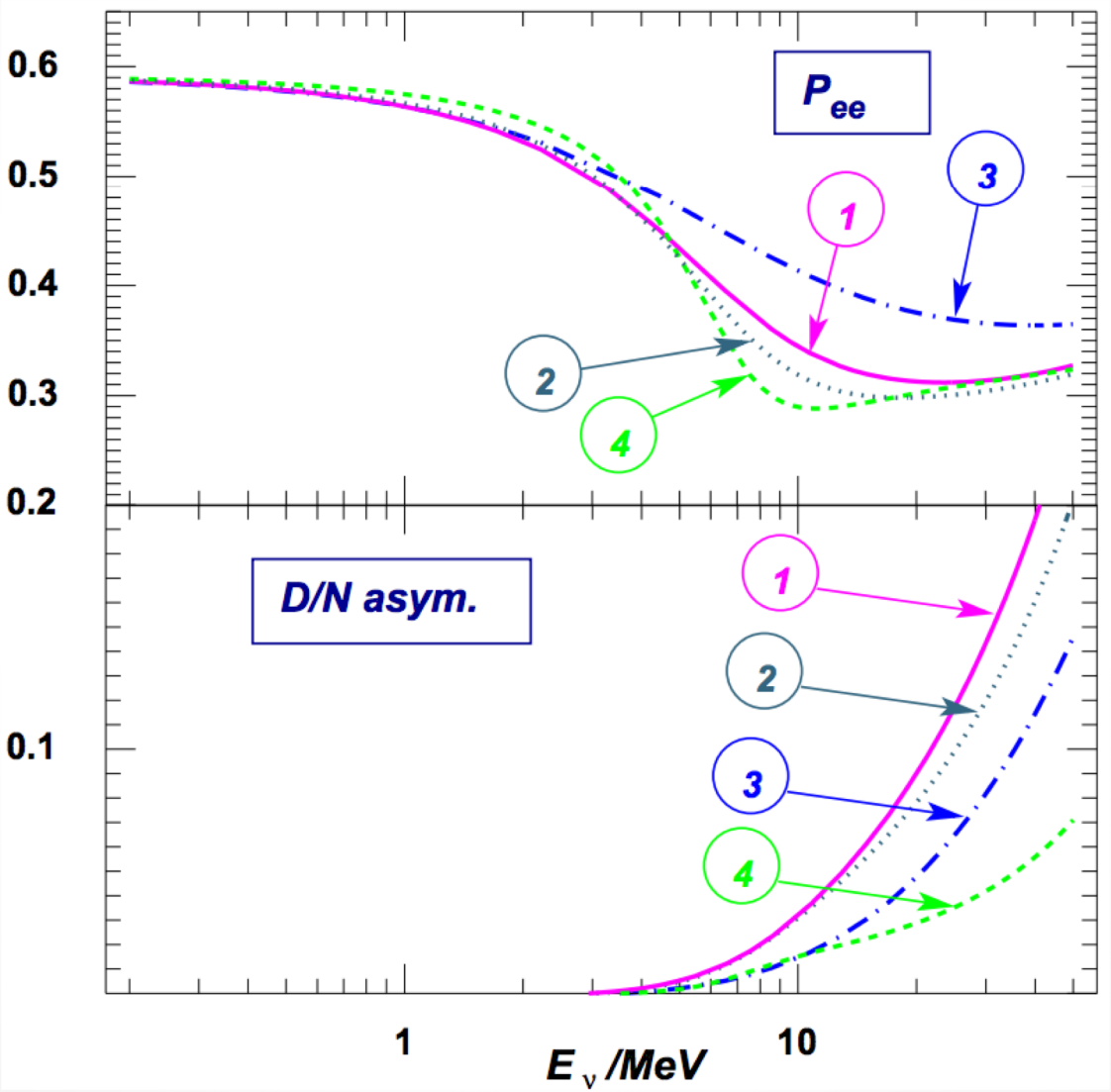
Solar: matter effect

Capozzi et al, 2018

Tension driven by day-night effect

New physics?

Friedland, Lunardini & Pena-Garay, 2004



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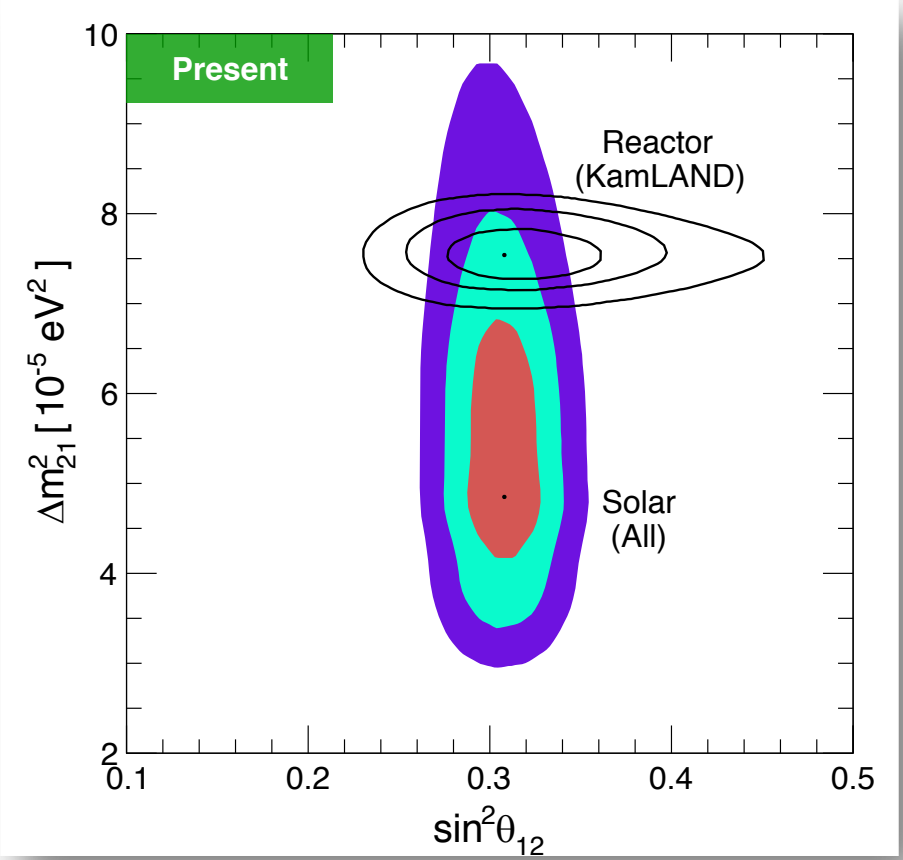
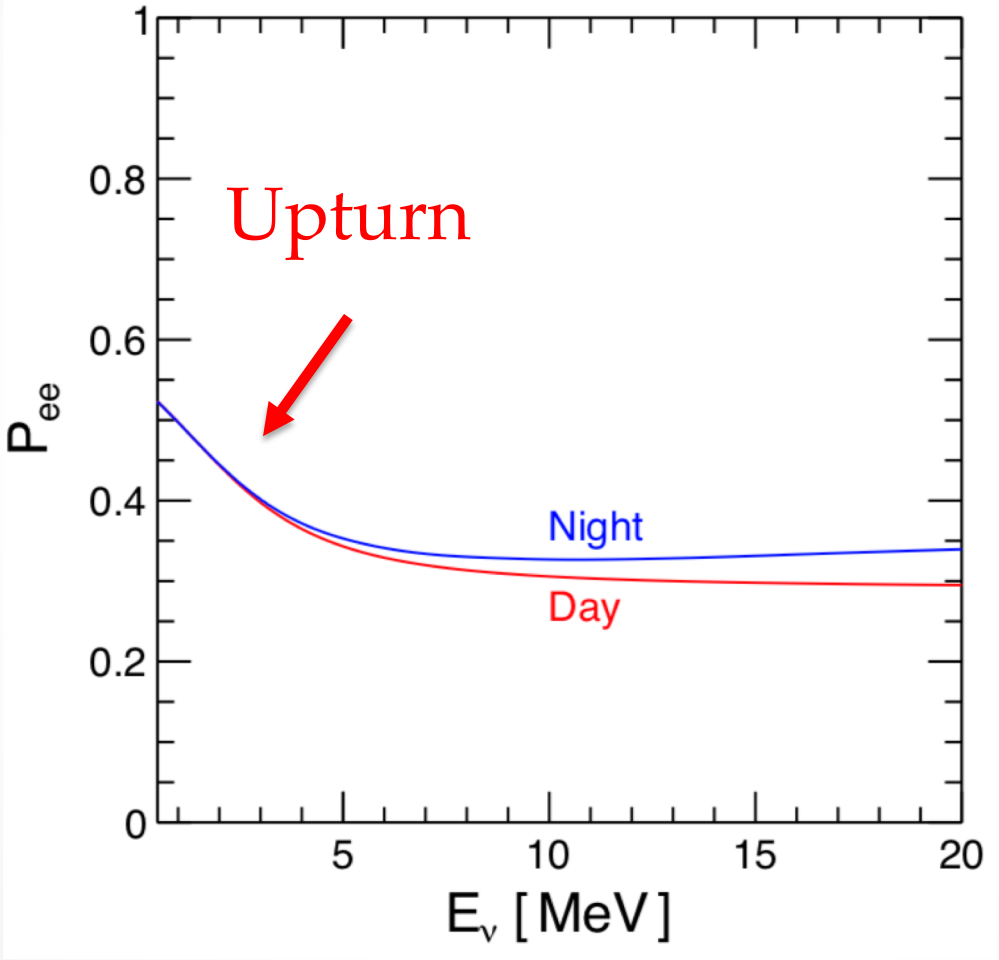


What is this?

Why haven't we resolved this?

What we want to measure

ϕ_{ν_e}/ϕ_ν as a function of neutrino energy



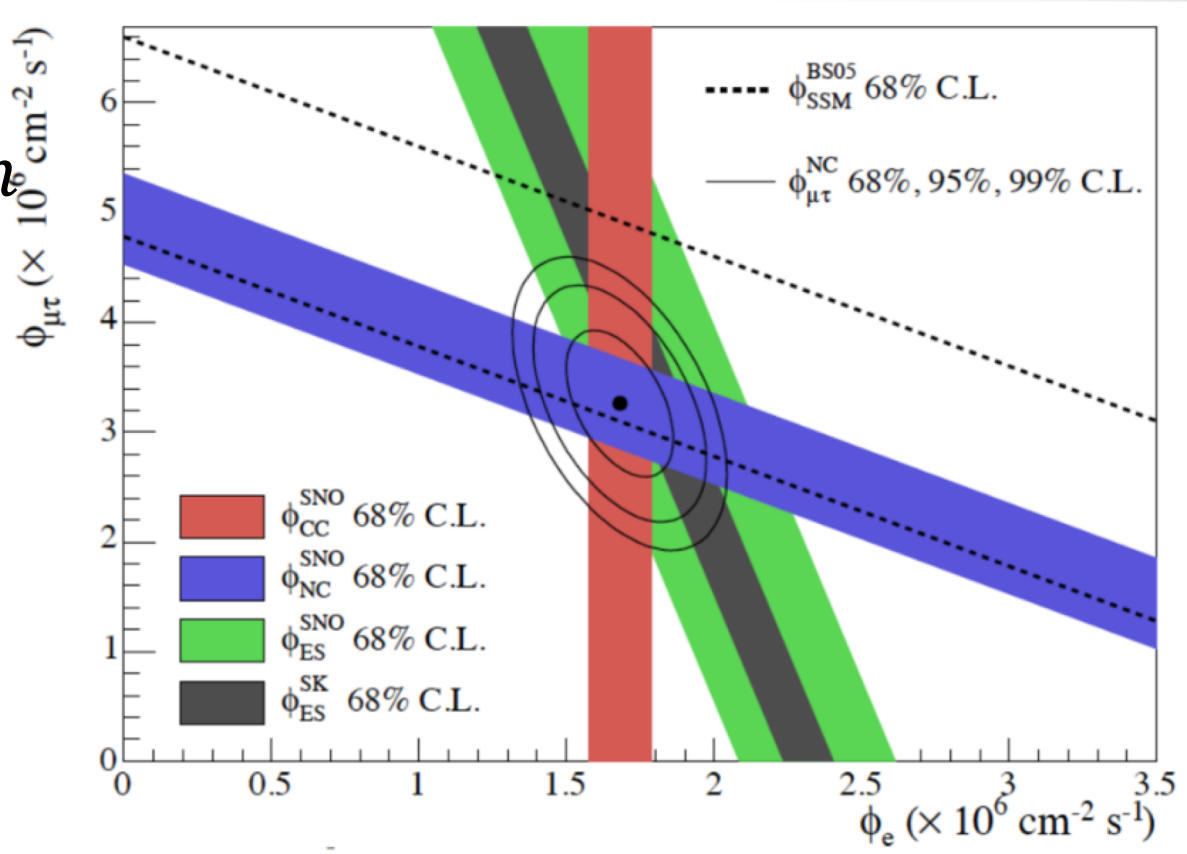
Capozzi et al, 2018

SNO: 1999 -- 2006

sno.phy.queensu.ca

Both NC and CC channel

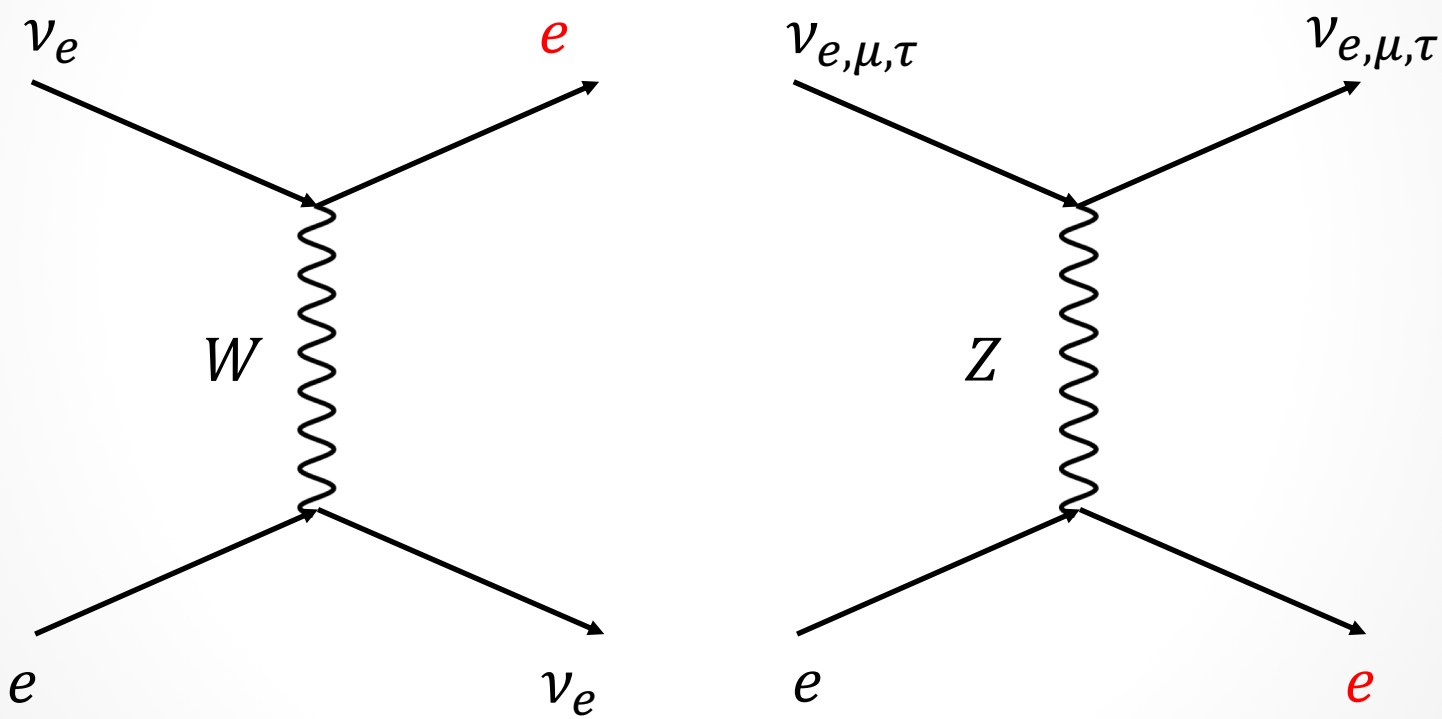
- $\nu_x + d \rightarrow \nu_x + p + n$
- $\nu_e + d \rightarrow e + p + p$
- $\nu_x + e \rightarrow \nu_x + e$



Provides ^{8}B ν flux: 4%

Super-K: 1996 -- present

ES channel only: $\nu_x + e \rightarrow \nu_x + e$



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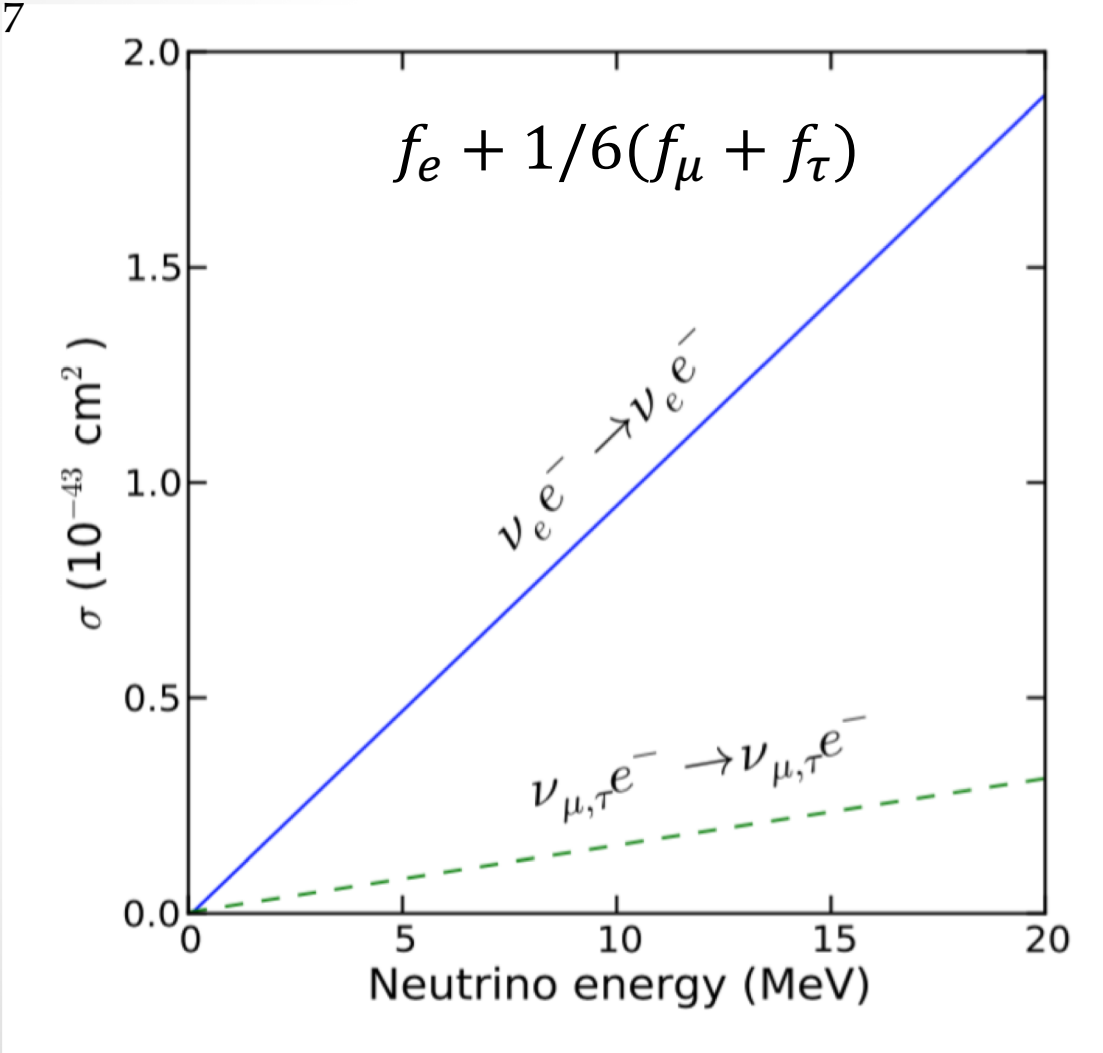
Li 2017

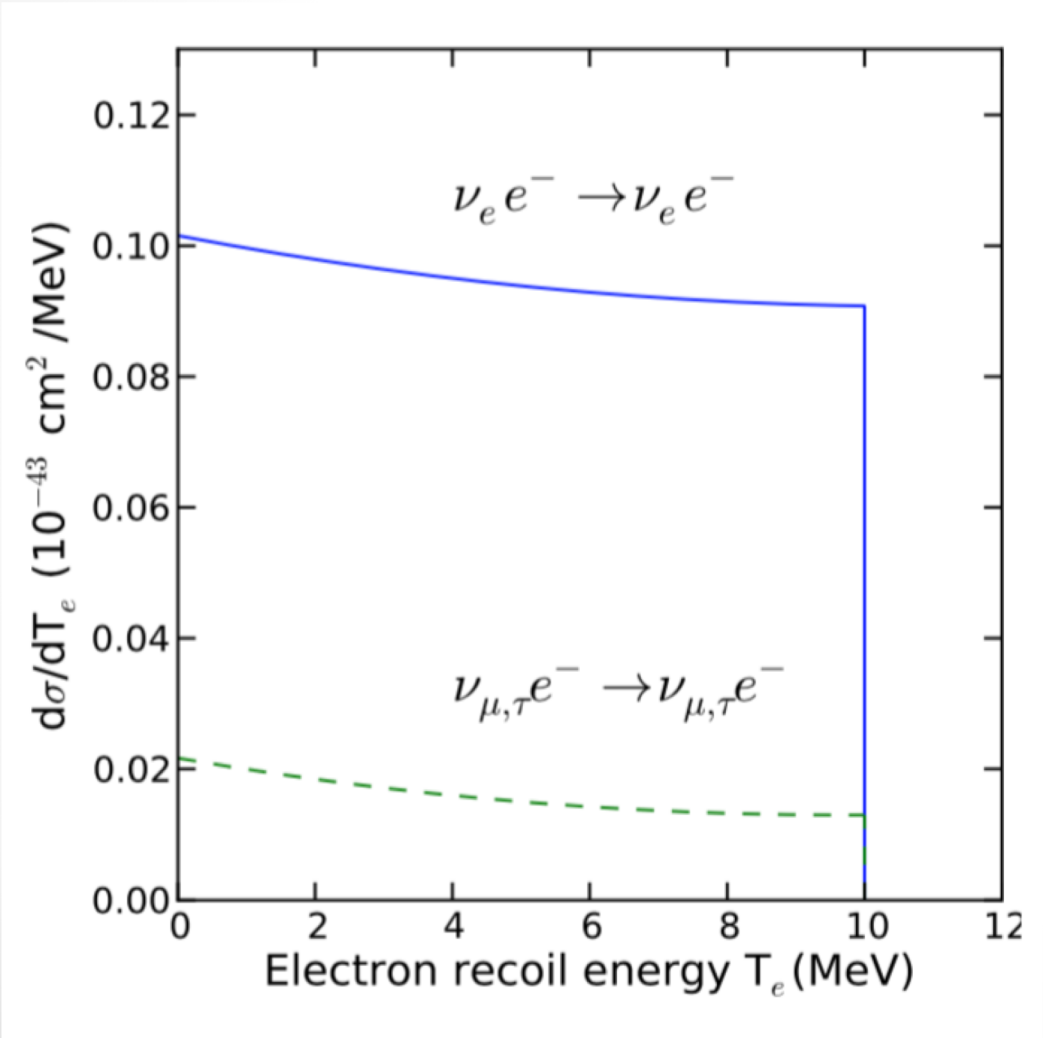


$\sin^2\theta$ limited by SNO flux

Super-K: 1996 -- present

ES channel only: $\nu_x + e \rightarrow \nu_x + e$

Li 2017



Neutrino energy dependence washed out

Smear δm^2

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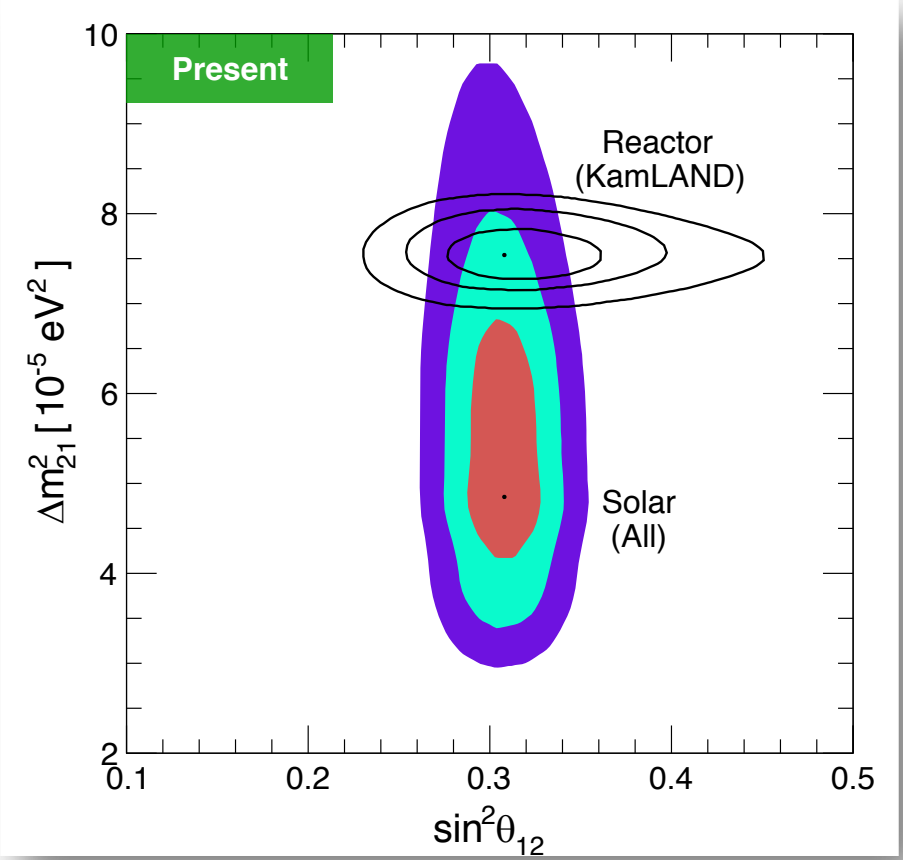


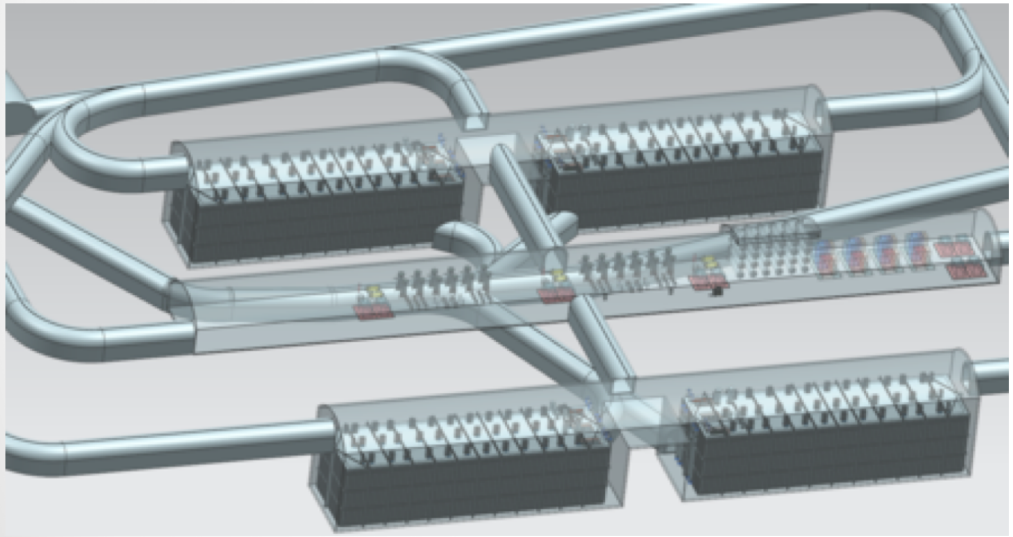
What is this?

Why haven't we resolved this?

DUNE

4 10-kton liquid argon TPC module

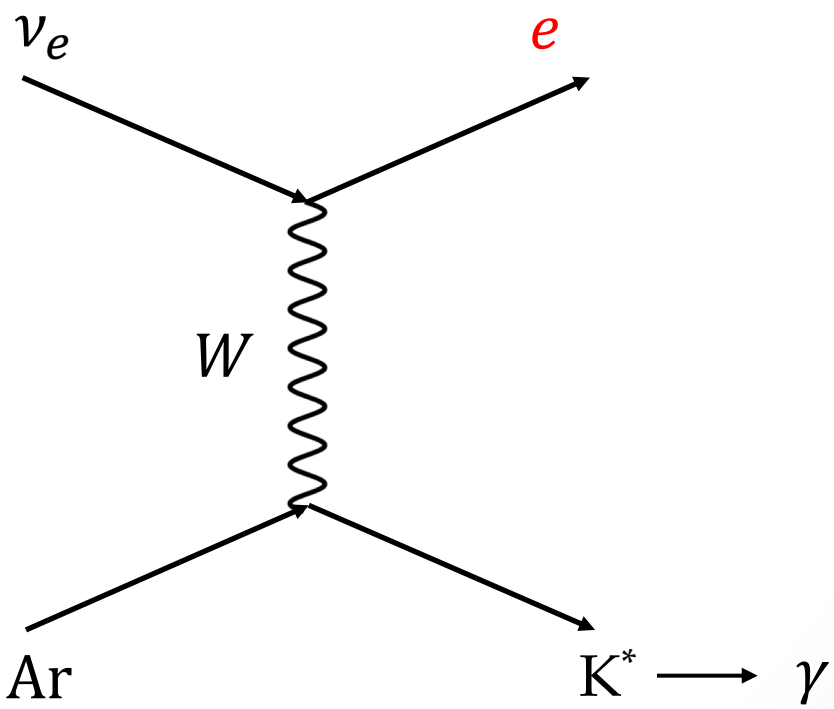
sciencemag.org



- Trigger
- $T_e > 5$ MeV
- Energy resolution 7%
- Angular resolution 25°

Unique advantage of DUNE

CC channel: $\nu_e + \mathrm{Ar} \rightarrow e + \mathrm{K}^*$



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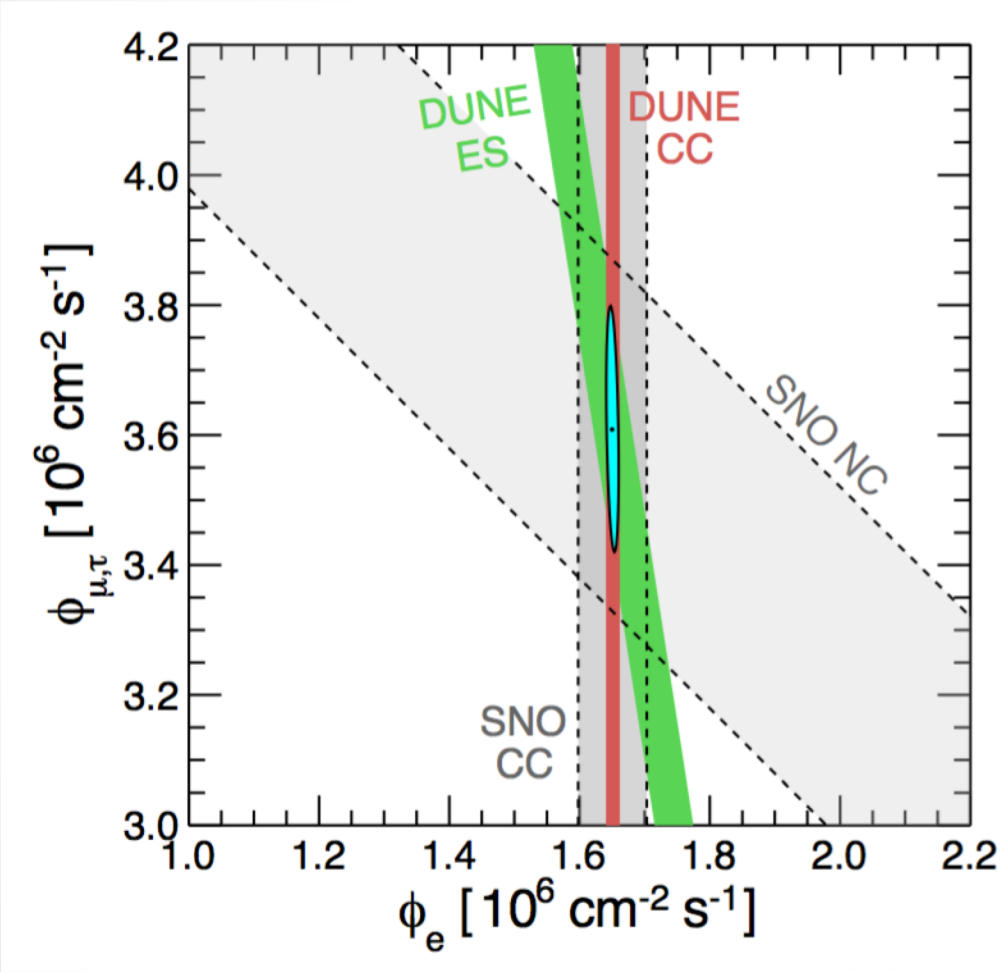

Combine with:

$\nu_x + e \rightarrow \nu_x + e$

Improve on $\underline{\sin^2\theta}$

Capozzi et al, 2018

Unique advantage of DUNE

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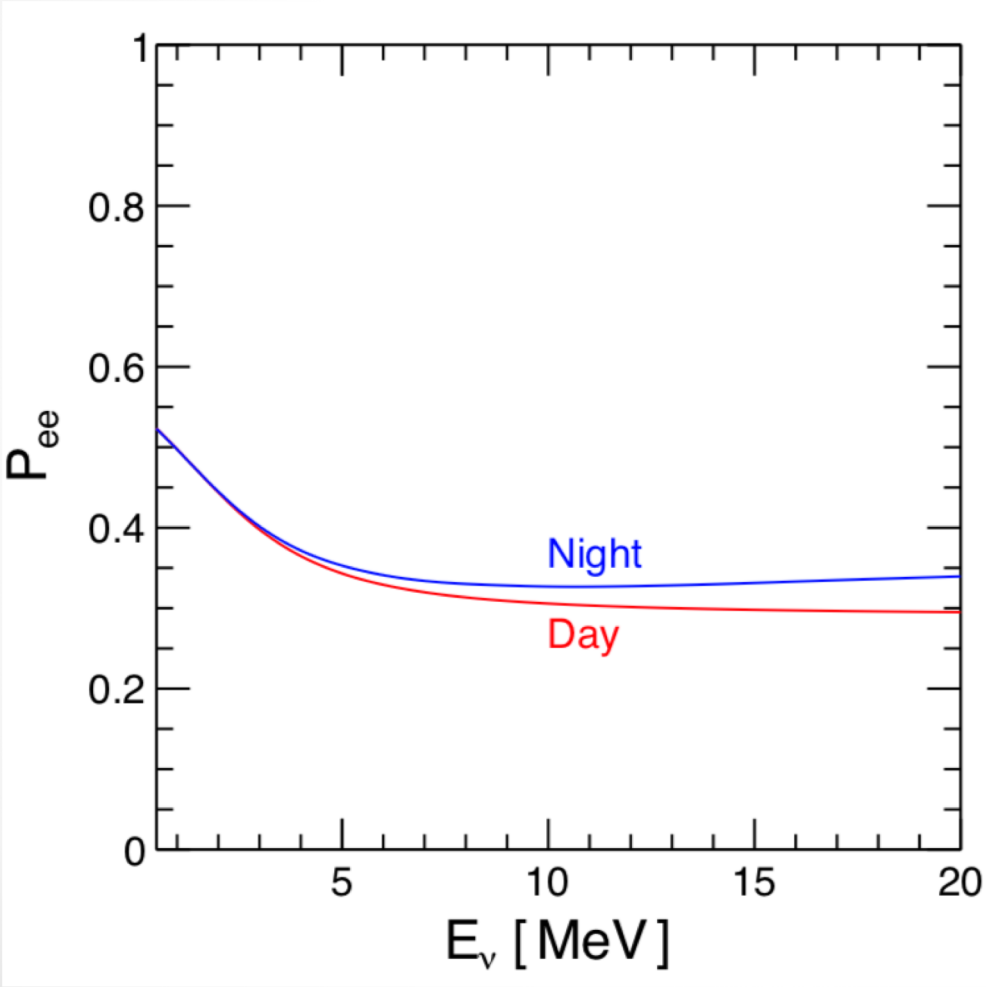


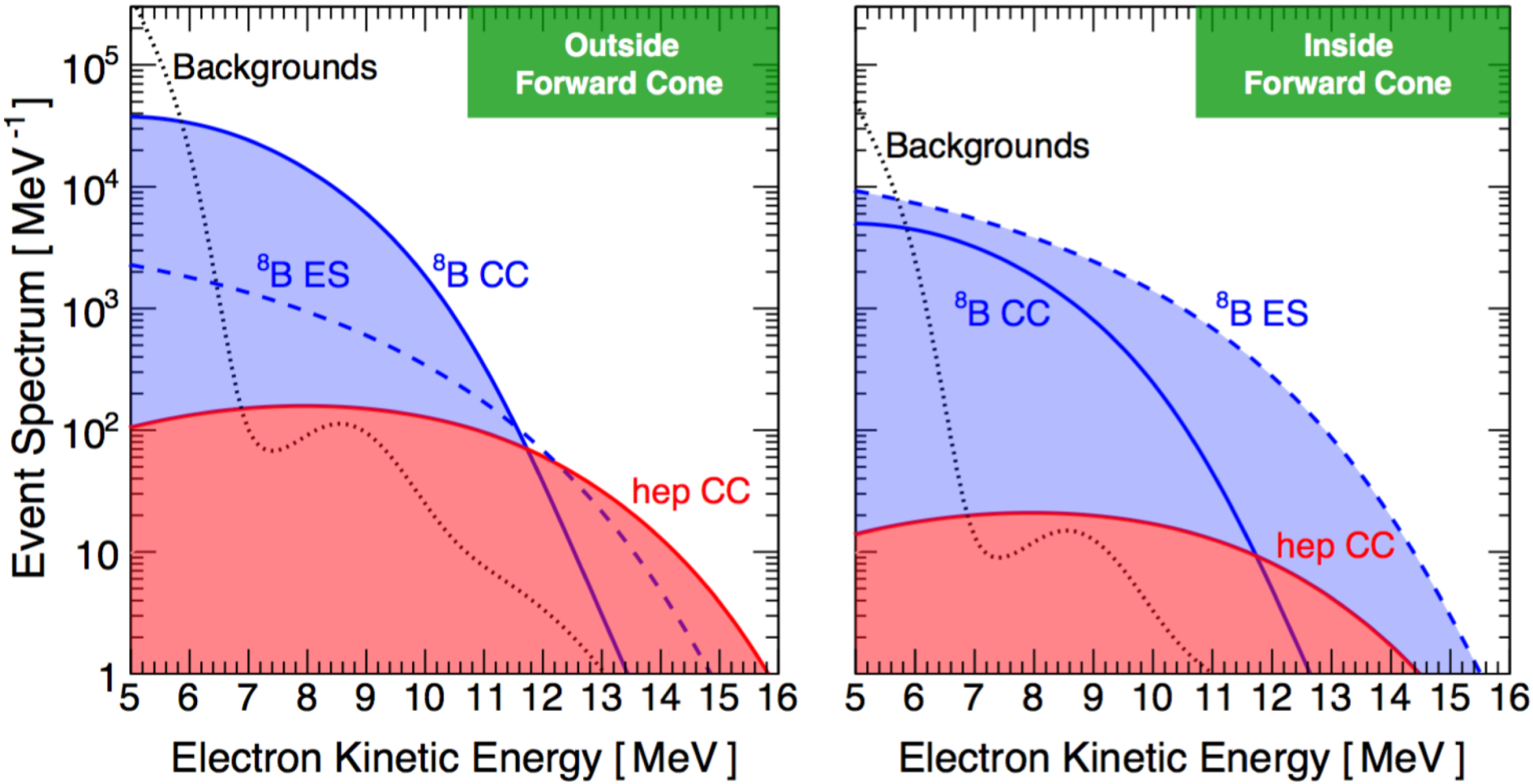
$$E_e = E_\nu - Q - \Delta\mathrm{E}$$

Improve on $\underline{\delta m^2}$

Capozzi et al, 2018

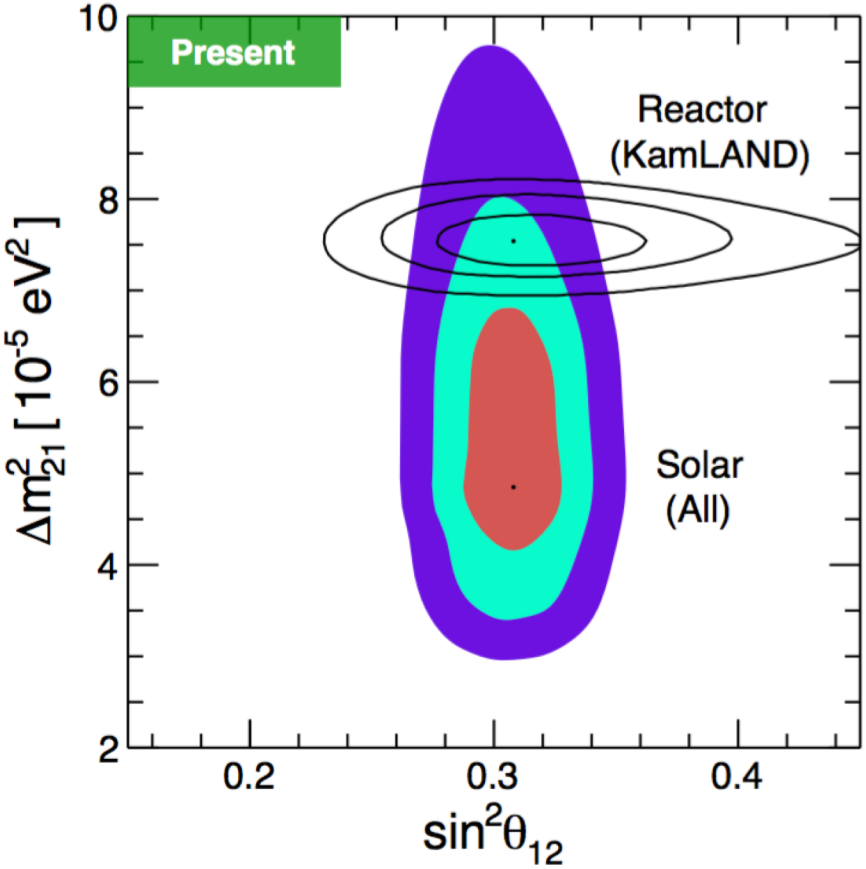
Event rate in DUNE

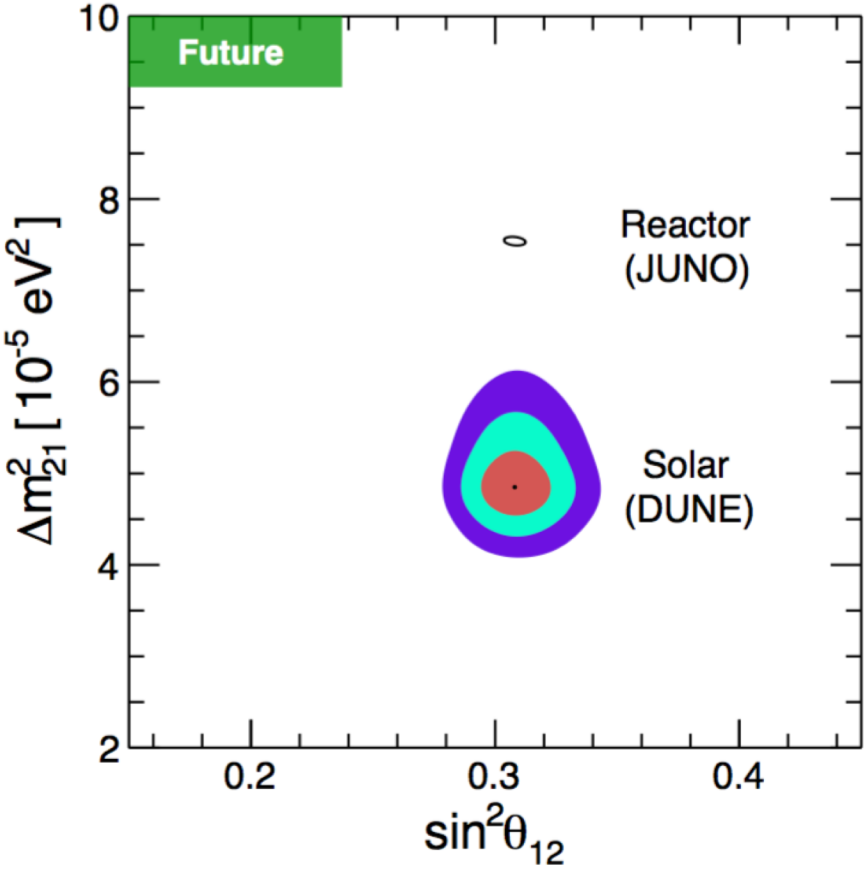
100 kton-year exposure



Capozzi et al, 2018

Results





Capozzi et al, 2018

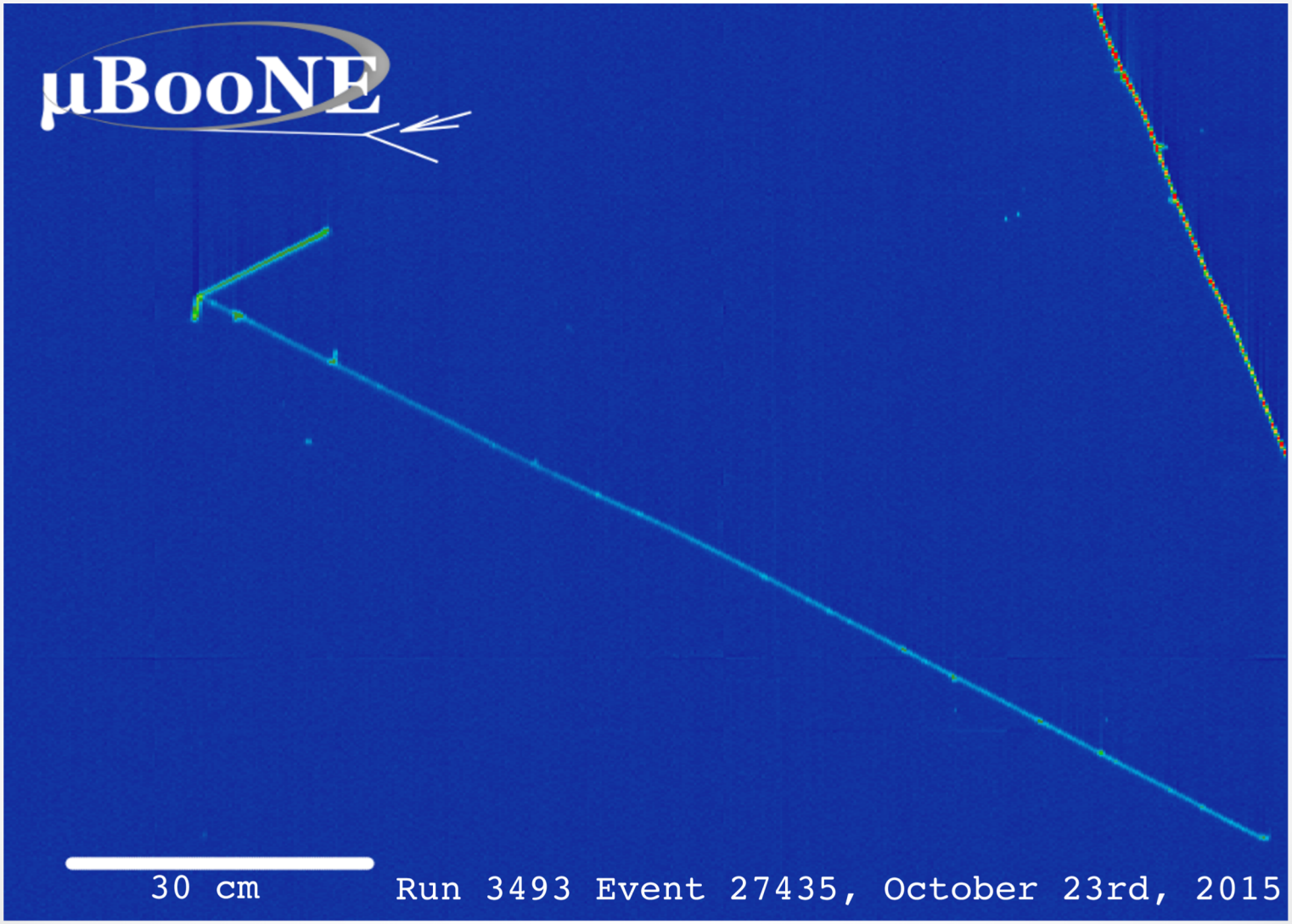
In addition, ^{8}B flux 2.5%, hep flux 10%

Solar neutrino in DUNE

…

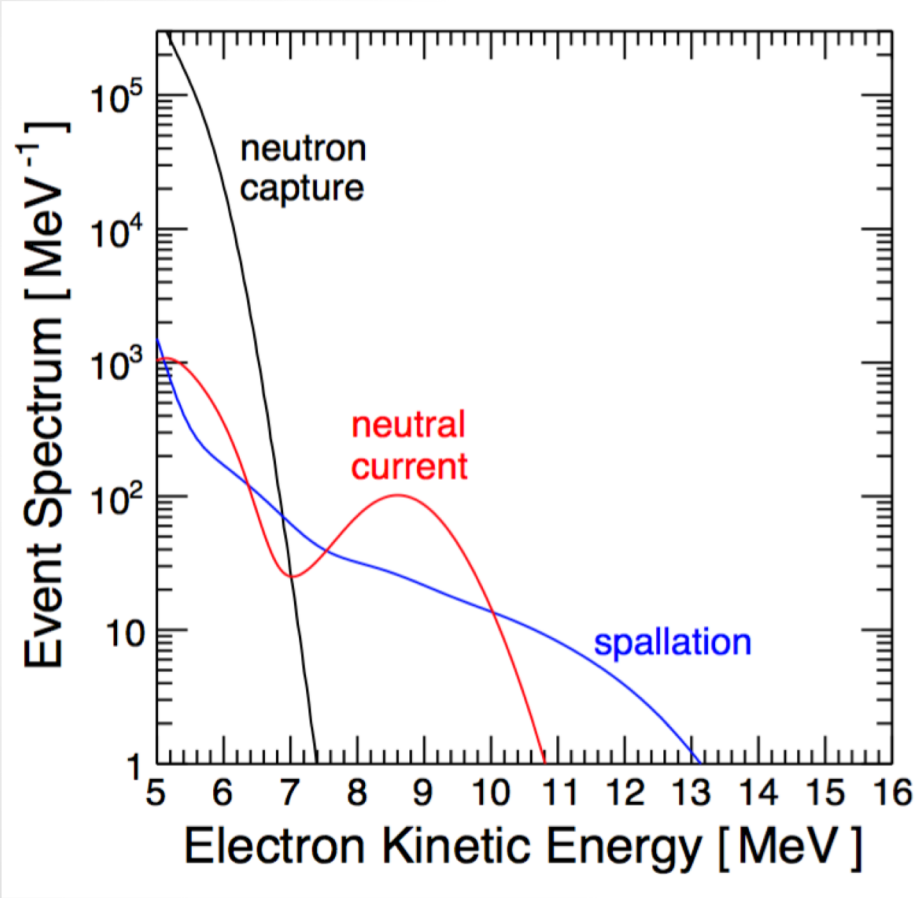
Program

Trigger



Backgrounds

Capozzi et al, 2018



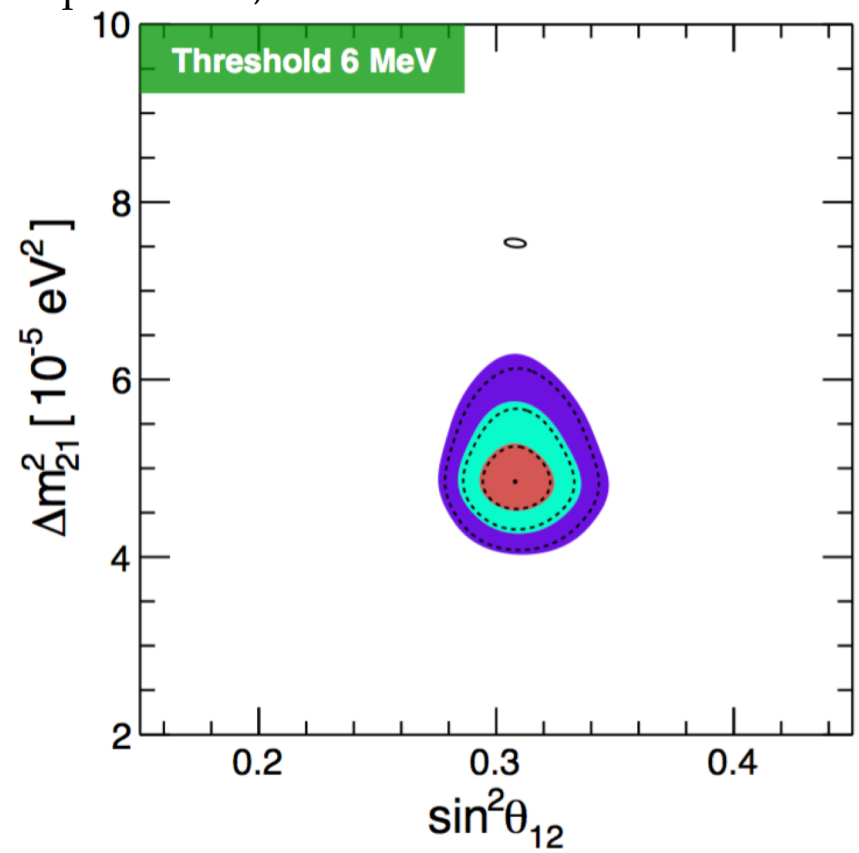
Three options:

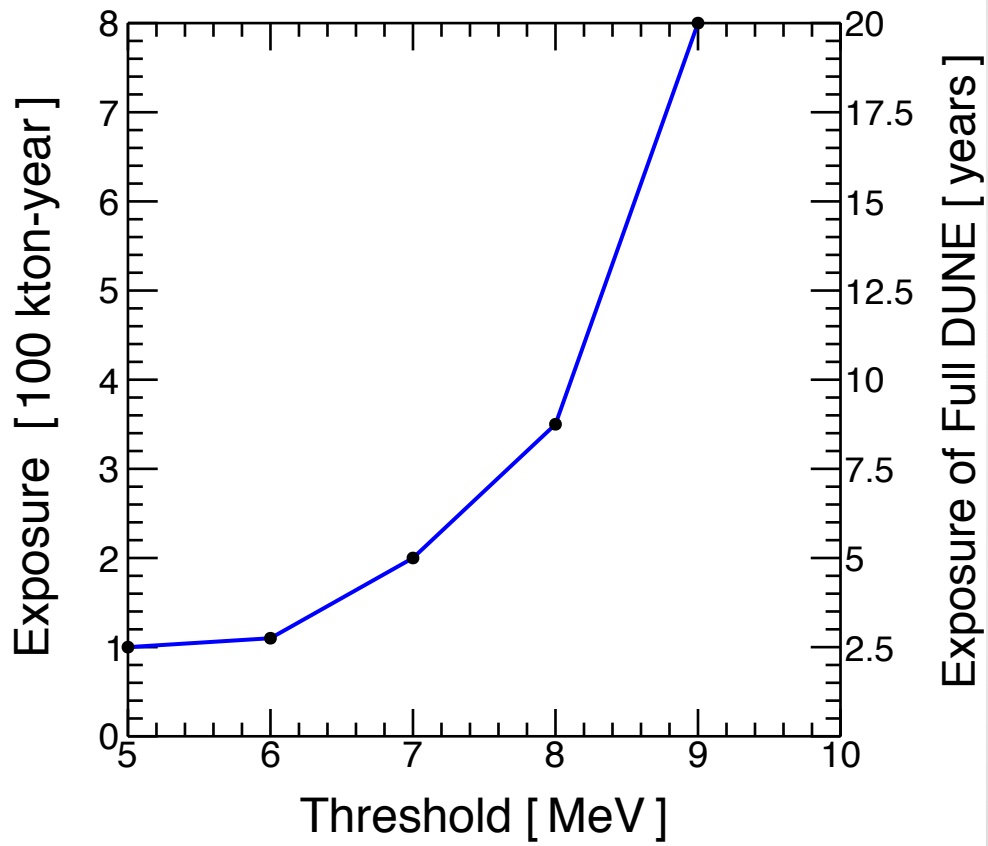
1. ~ 40 cm of water/plastic shielding
2. Double the exposure
3. Reconstruct neutrino energy

Threshold

Depends on reconstruction & background level

Capozzi et al, 2018

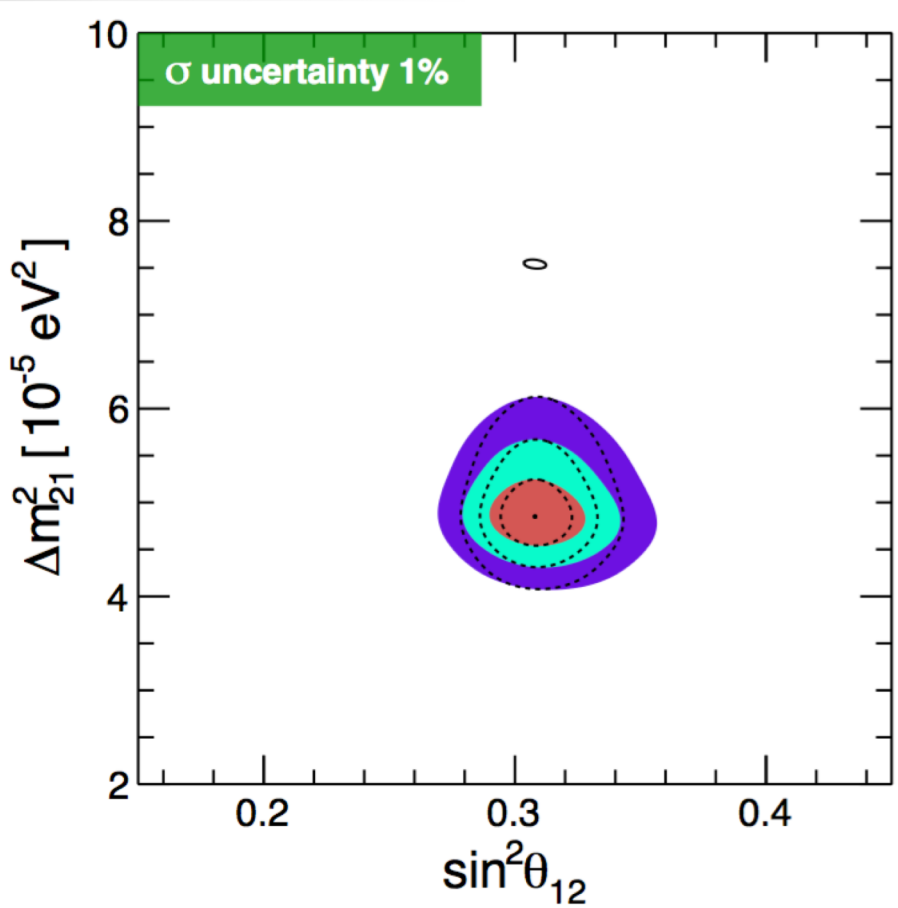


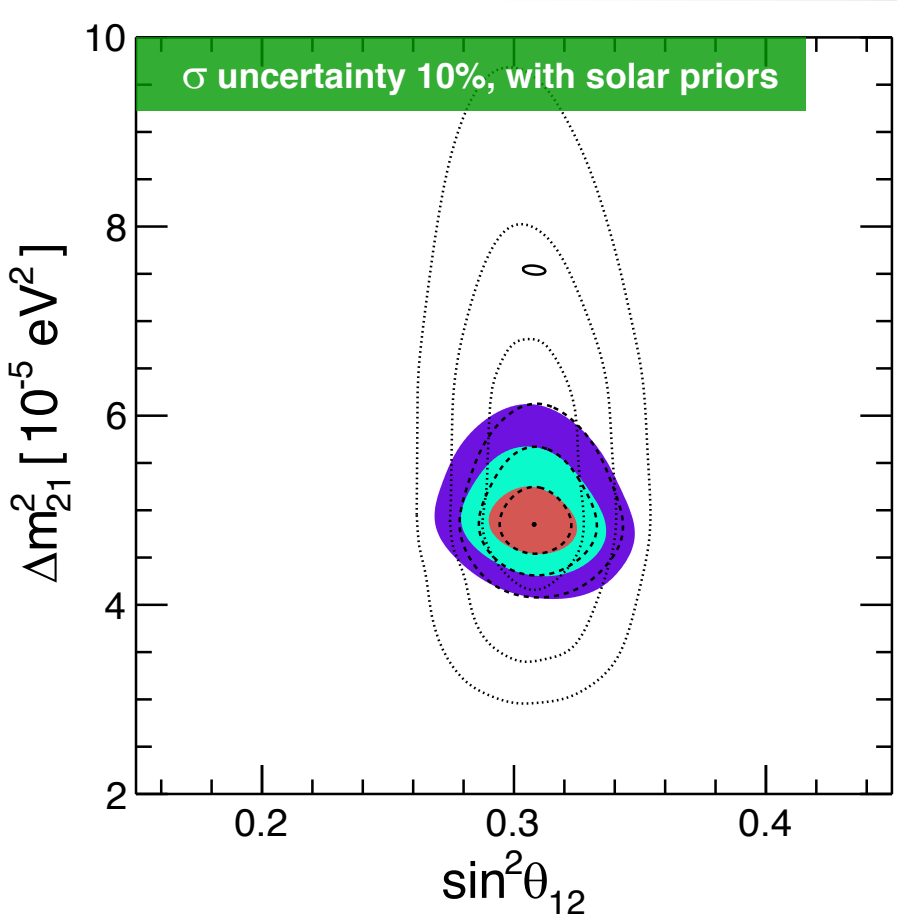


Can be compensated by larger exposure

Cross section

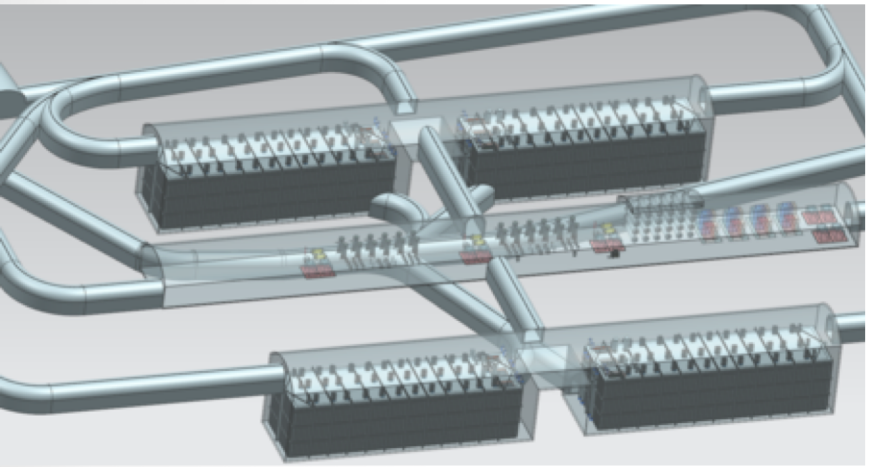
Current uncertainty: a few %

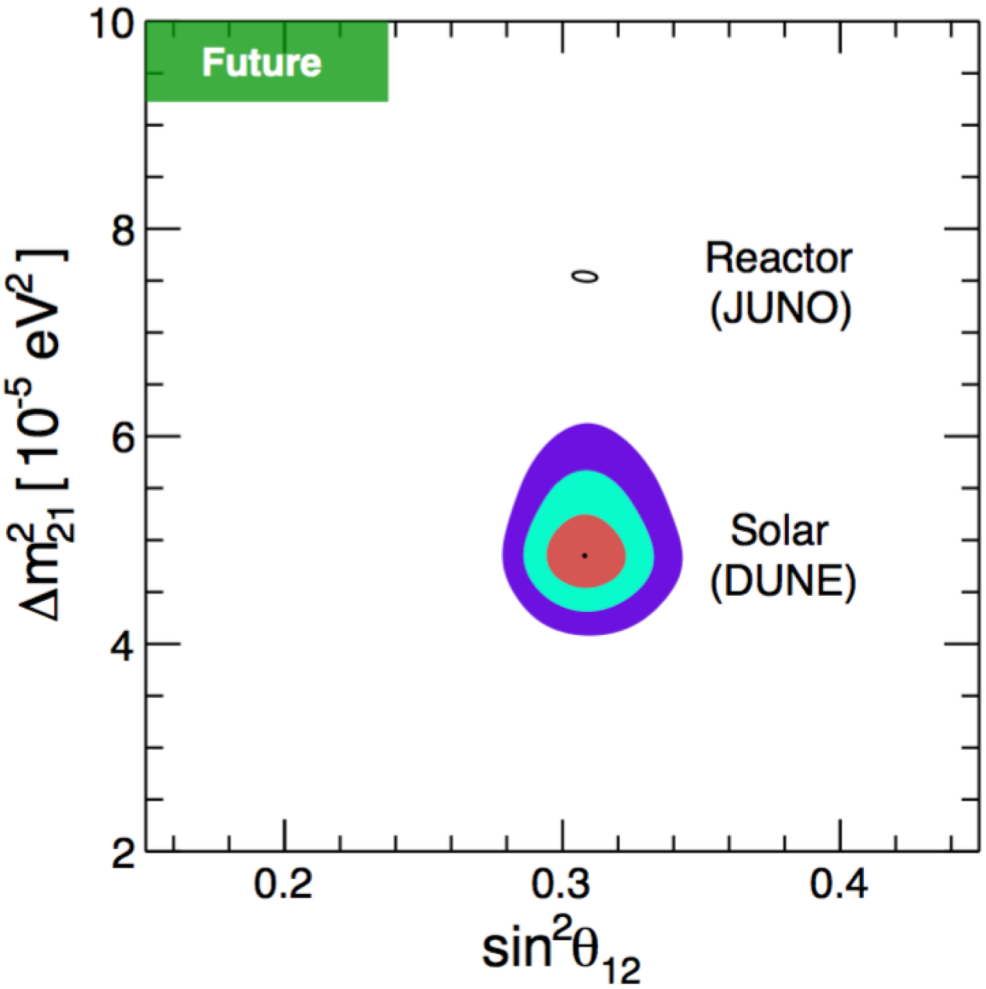




Capozzi et al, 2018

Conclusions





Back up

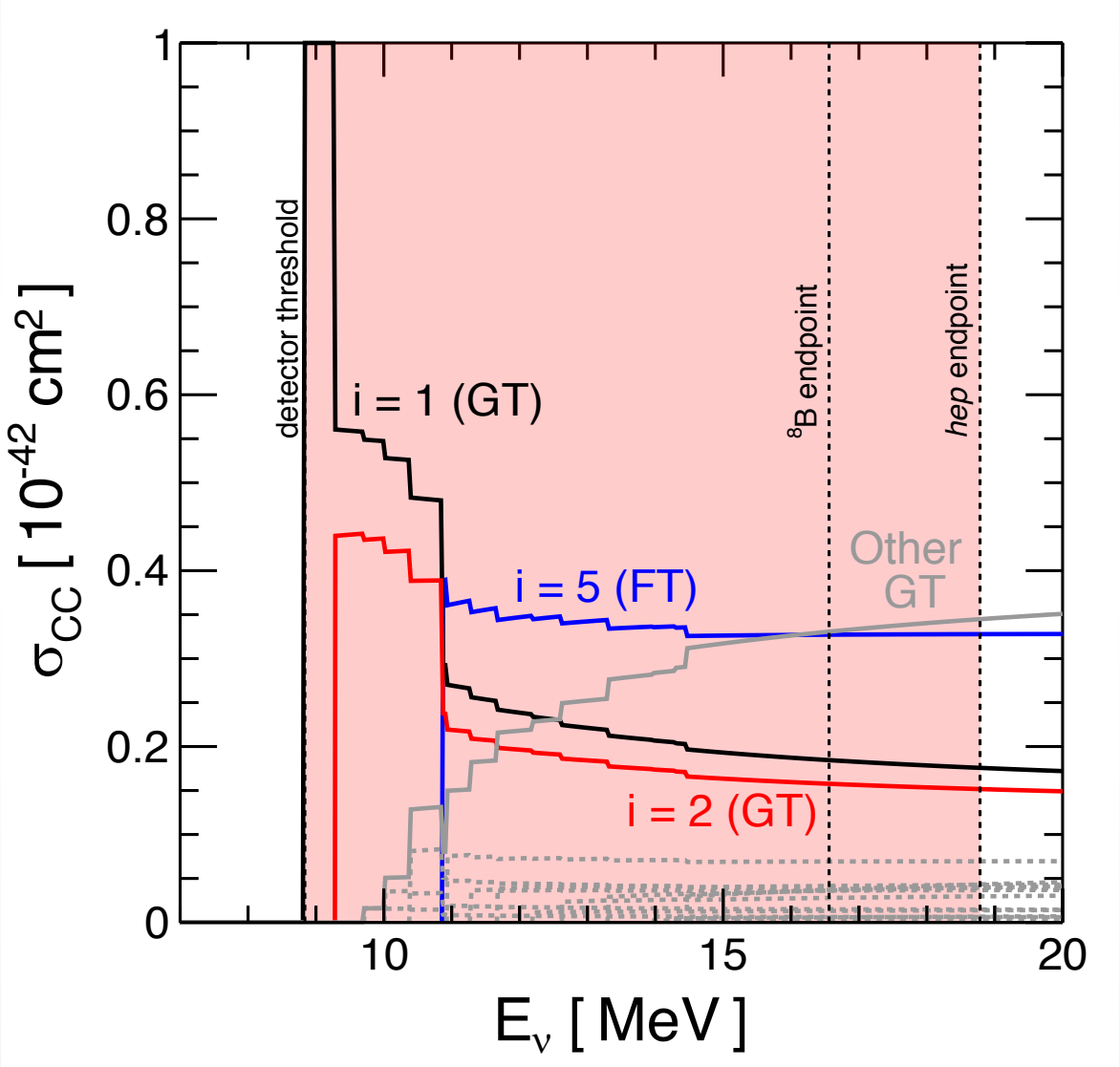
Measured metallicities

Element	GS98	AGSS09met
C	8.52 ± 0.06	8.43 ± 0.05
N	7.92 ± 0.06	7.83 ± 0.05
O	8.83 ± 0.06	8.69 ± 0.05
Ne	8.08 ± 0.06	7.93 ± 0.10
Mg	7.58 ± 0.01	7.53 ± 0.01
Si	7.56 ± 0.01	7.51 ± 0.01
S	7.20 ± 0.06	7.15 ± 0.02
Ar	6.40 ± 0.06	6.40 ± 0.13
Fe	7.50 ± 0.01	7.45 ± 0.01
$(Z/X)_\odot$	0.02292	0.01780

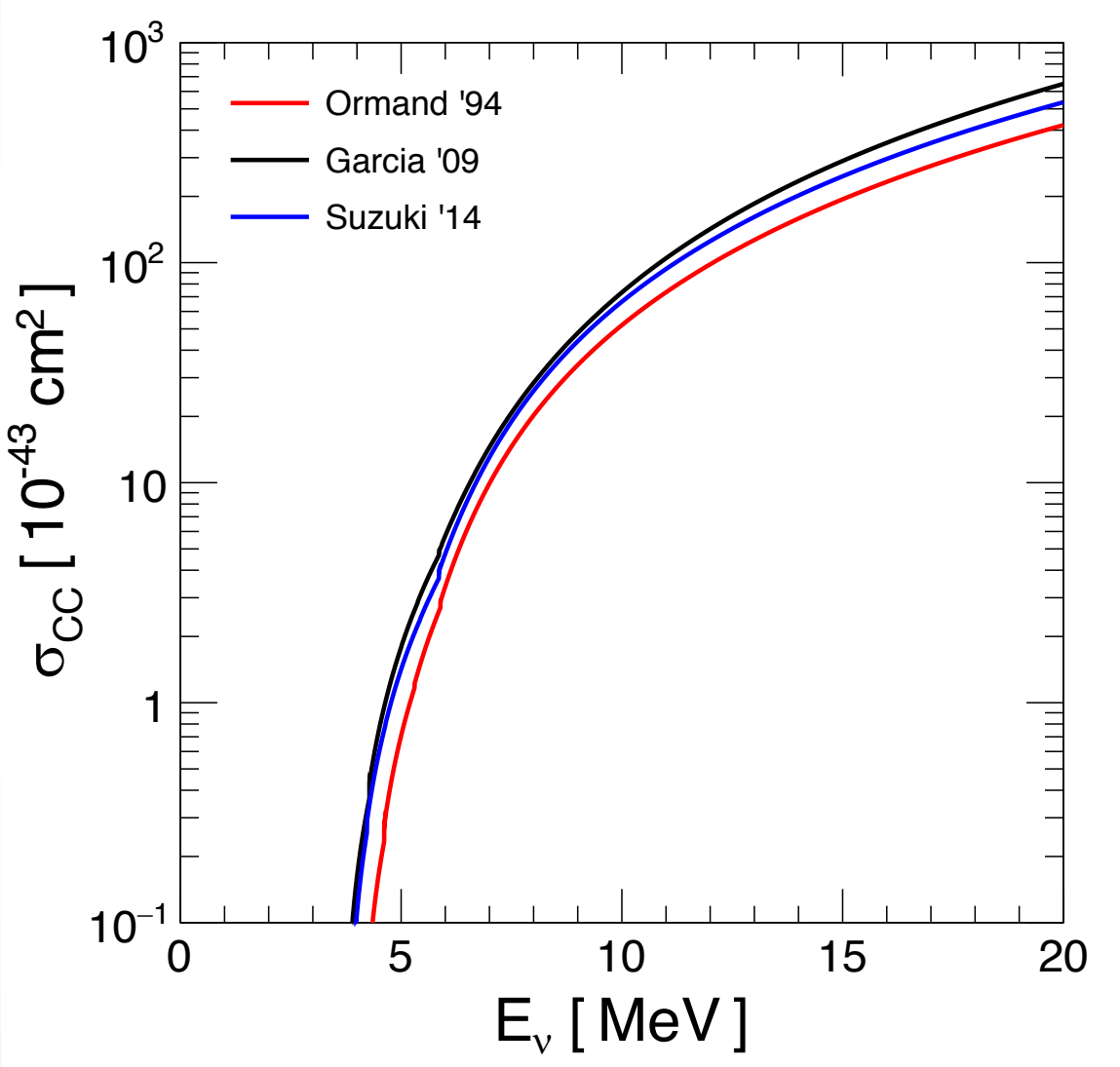
Cross section

i	ΔE_i [MeV]	B_i(F)	B_i(GT)
1	2.333		1.64
2	2.775		1.49
3	3.204		0.06
4	3.503		0.16
5	3.870		0.44
6	4.384	4.00	
7	4.421		0.86
8	4.763		0.48
9	5.162		0.59
10	5.681		0.21
11	6.118		0.48
12	6.790		0.71
13	7.468		0.06
14	7.795		0.14
15	7.952		0.97
total		4.00	8.29

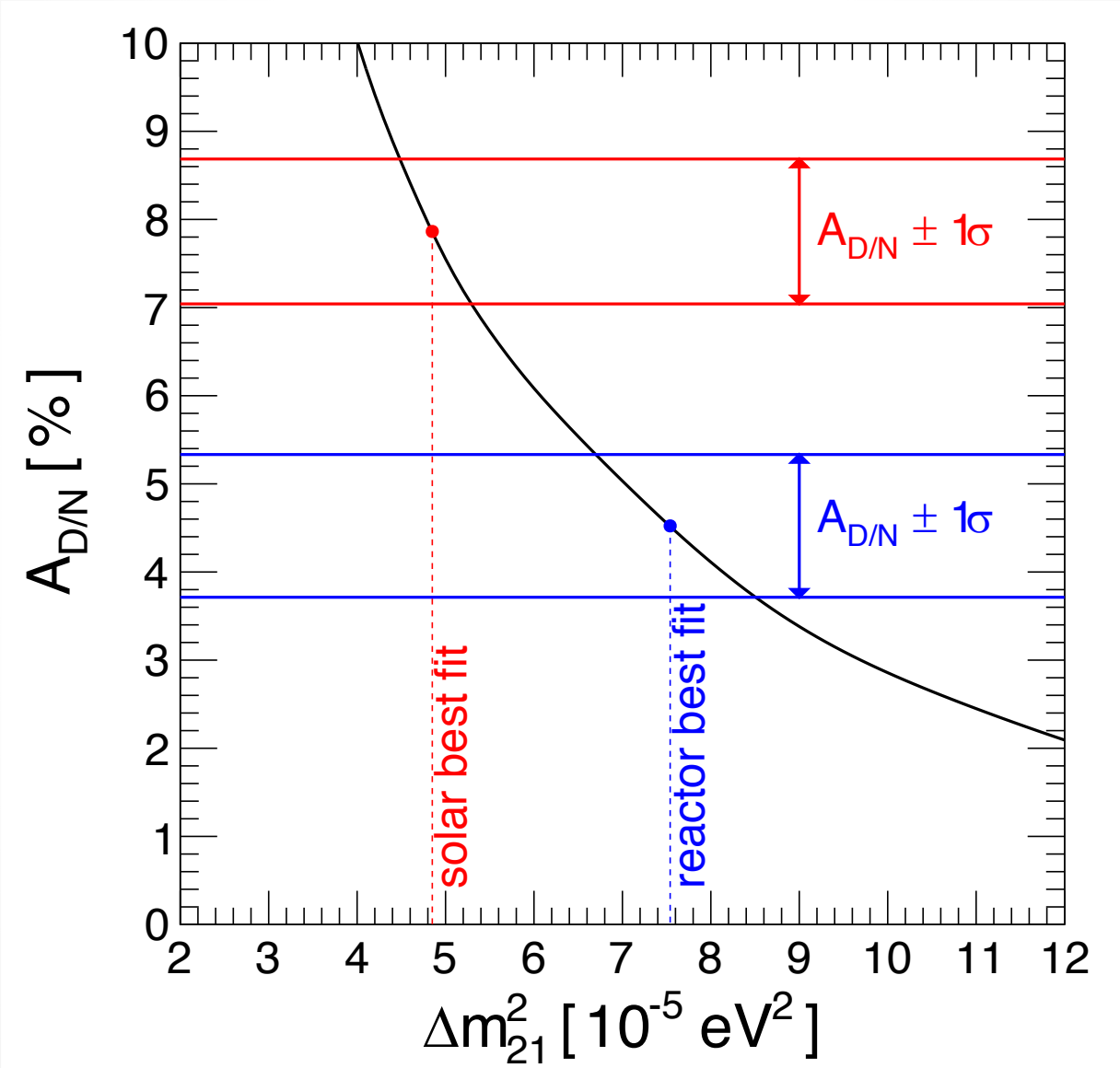
Cross section



Cross section

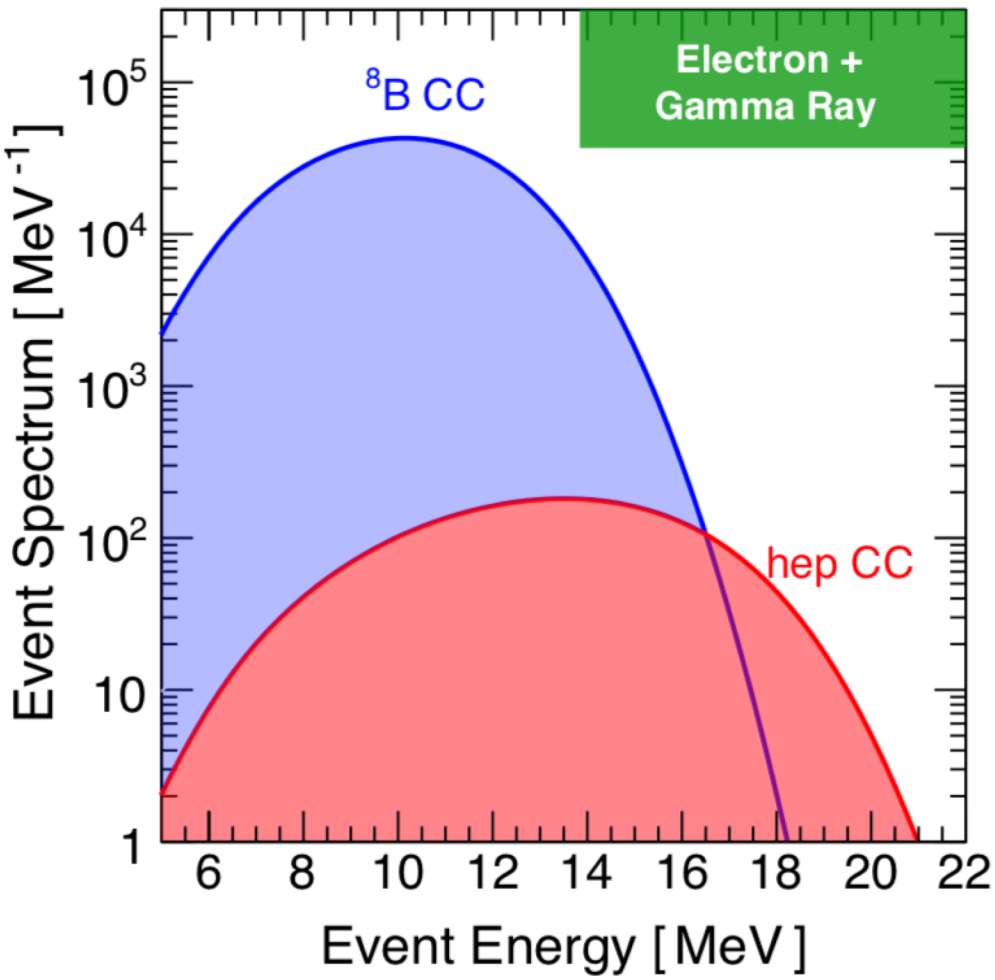


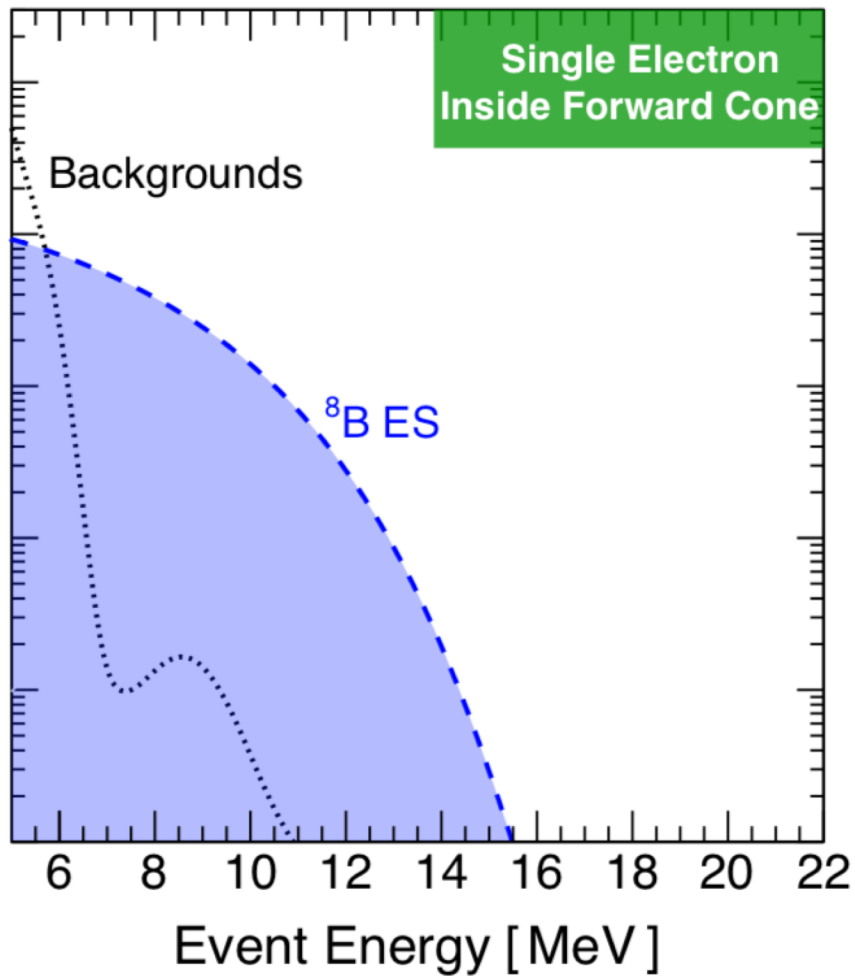
Mass square sensitivity



PID

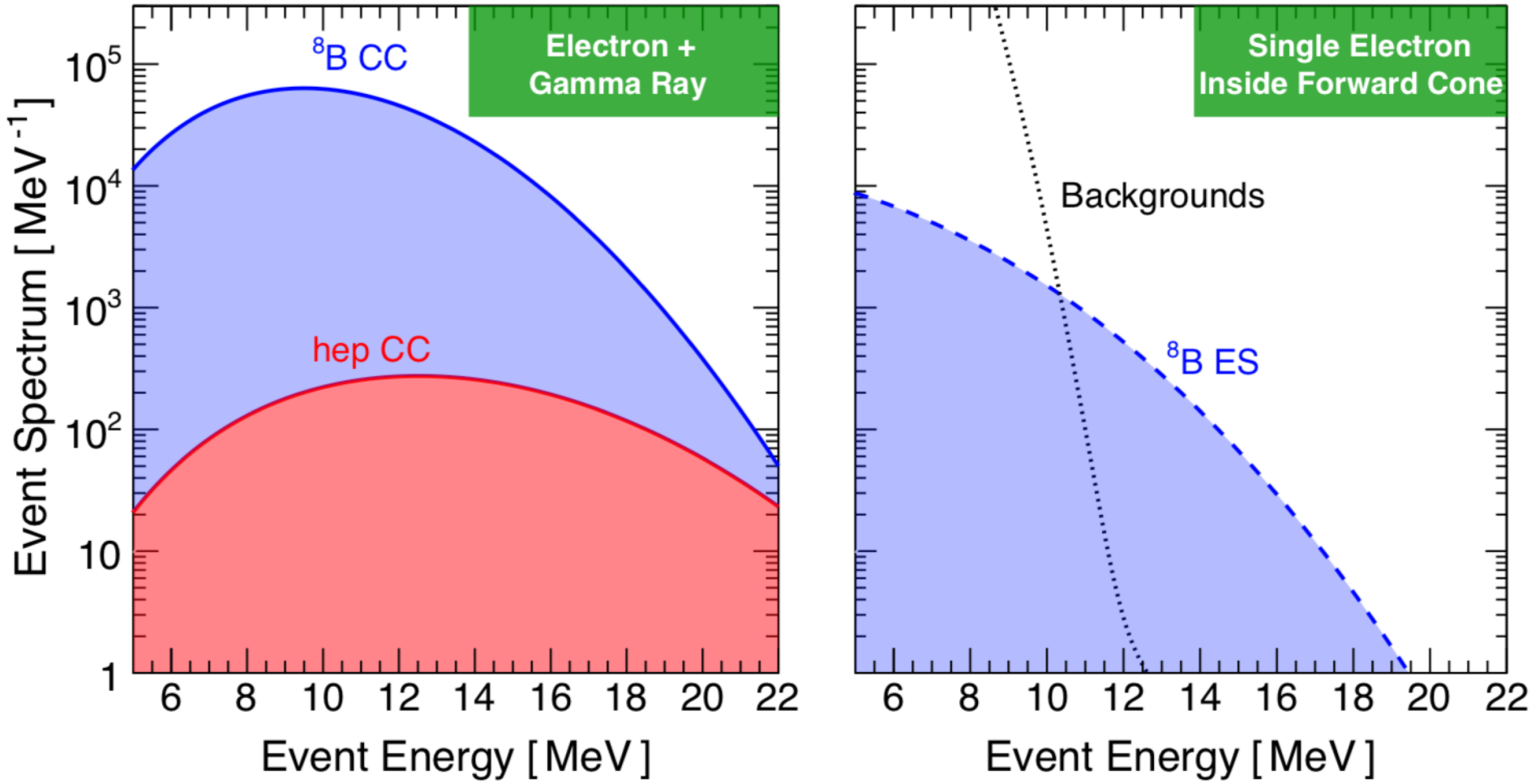
7% energy resolution





PID

20% energy resolution



Systematics

energy scale, energy resolution, shape